WORKSHOP ON CLIMATE VARABILITY AND WATER RESOURCE MANAGEMENT IN THE SOUTHEASTERN UNITED STATES

DRAFT SUMMARY

Held at Vanderbilt University
Nashville, Tennessee
June 25-27, 1997

Sponsored by
National Aeronautics and Space Administration
National Oceanic and Atmospheric Administration
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EXECUTIVE SUMMARY

A regional workshop on Climate Variability and Water Resource Management in the Southeastern United States was held at Vanderbilt University in Nashville, Tennessee on June 25-27, 1997. The workshop was jointly sponsored by the National Aeronautics and Space Administration (NASA), National Oceanic and Atmospheric Administration (NOAA) and the US Geological Survey (USGS). This is one of a series of workshops on the effects of climate variability and climate change on the regional environment and regional economics. These workshops are being coordinated by the US Global Climate Change Research Program (USGCRP) and the Office of Science and Technology Policy (OSTP). They are expected to identify and examine high priority regional environmental issues affected by current climate variation and future climate change. Information will be assembled at the regional scale that can eventually be aggregated across regions to support the identification of climate-related impacts and vulnerabilities at the national scale.

The overall purpose of the Southeastern Regional Workshop was to examine the impacts of climate variability and potential vulnerability to future climate change on various economic sectors, with an emphasis on water resources, in the following southeastern states: Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina and Tennessee. In addition to examining the regional vulnerability of current climate variability and future climate change, the workshop was organized to initiate dialogue between federal agencies and universities engaged in climate-related research with key regional stakeholders who are responsible for day-to-day management operations.

At the workshop, Dr. Jim O'Brien of Florida State University demonstrated the enormous effect that El Nino and its opposite El Viejo has on the climate variability of the southeastern US. When there is an El Nino in the winter, for example, we can expect a reduction in hurricanes, reduction in tornadoes, winter rain, cool temperatures, but an adverse effect on crops in Florida. On the other hand, when there is a cool tropical Pacific Ocean (El Viejo or La Nina), we can expect more hurricanes, forest fires in coastal regions of the Carolinas and in south Florida. In addition, we can have adverse effects on many crops.

Dr. O'Brien also reported that the southeastern US does not seem to be affected by the North Atlantic Oscillation but is still affected by interdecadal variability which changes the frequency of the ENSO (El Nino-Southern Oscillation) phenomena. Global climate change has created mild cooling in the southeastern US.

During the workshop four basic themes became apparent. First, the regional infrastructure in the areas covered during the breakout discussions is already being stressed by near-term weather and climate variations. In addition, meeting current day-to-day operations consumes most of the time and budget of a regional stakeholder in the absence of climate-related issues. If the magnitude of climate variability increases or there are more frequent extreme events, the system will be stressed even further. Incorporating climate variability and change into these operational decisions will only exacerbate this situation.

Second, although our climate predictive skills are improving, especially with short-term forecasts (i.e., up to 72 hours) and data are currently available or are emerging from the climate community, this information is not widely used by the regional stakeholders. In essence, there has been an inadequate communication of climate risk at the regional and local levels. Decision-makers at these levels want additional information on climate variability and change if they can obtain answers to questions about the magnitude of effects, the timing, and the potential costs. Given the inherent uncertainties in recognizing climate change against a background of normal climate variability, regional stakeholders must decide in a world of considerable uncertainty. The workshop intended to highlight some of the new approaches and new data emerging from the climate community. It is anticipated that this workshop and any follow-on efforts will help mold these approaches and data for better use by the regional stakeholders.

Third, regional stakeholders are generally unable to effectively use information, data, and products that are available from the climate community. A clearer understanding of the products that are available or will be available in the near future from the scientific community is greatly needed. Individual scientists performing research are not generally expected to negotiate and communicate their results directly with the policy- and decision-makers. An exerted effort will be required to identify scientific results that can be used in the public and private sectors and can contribute more directly to near-term economic and societal applications. One cause of the current deficiency is that existing delivery or distribution systems (e.g., county extension program for agriculture) are not generally linked to the outputs of the climate community.

Fourth, stronger partnerships among federal and academic researchers, regional, state, and local stakeholders, and the private sector are needed to adopt and incorporate advanced science results, technology, and data products into everyday decision-making. Better linkages are required between researchers and regional stakeholders to define better the needs of a broader user community and to identify scientific results that will meet these needs. The use of selected pilot studies that demonstrate this approach is strongly encouraged.

The workshop consisted of plenary talks that set the context and framework and also breakout discussions. In the plenary sessions several topics were covered such as current climate variability in the Southeast, climate and weather extreme events and their social and economic consequences, perspectives of the regional stakeholders, global climate change trends in the Southeast, and the educational aspects of climate. The breakout sessions were focused on important economic sectors including: agriculture, coastal and fisheries, education, extreme events, parks and public lands, urban areas and human health, and water resources.

The following four questions were posed in each of the breakout sessions:

- What are the current concerns and stresses of the regional stakeholders in each sector?
- How can current climate variability and climate change amplify these concerns and stresses?
- What information and data is needed to address these climate-related issues?
- What types of strategies and approaches are available for coping with or mitigating these stresses?

The responses to these questions served as points for discussion within the breakout session and as the major output of the workshop. In this summary, we provide a set of key findings and recommendations that represent the deliberations of the seven working groups and the final, plenary session. These findings are either unique to the Southeast or are important enough to warrant serious consideration in future national assessments. There are gaps in the areas considered in these recommendations, especially for forestry and fisheries. These gaps will be addressed in future workshops and discussions. The full set of findings and recommendations for each of the breakout topics are also presented as a record of the workshop discussions.

There is much more to learn about the effects of climate variability and climate change on the key economic sectors in the Southeast. The findings and recommendations of this workshop provide a beginning discussion on what is important and how to proceed. It is expected that these recommendations will be reviewed and updated at regular intervals. In this way, we can better prepare for an uncertain future.

Key Findings and Recommendations

Water Resources

Findings:

- The overriding water resources issue in the Southeast is that the demand for water is beginning to exceed the available supply and competition among water uses is intensifying. This competition for water is exacerbated by climate variability and change.

- As water conflicts in the Southeast have intensified, it has become apparent that there are inadequate mechanisms for the equitable allocation of water. Since some of the most important water issues are not of a technical nature, but are political, social, and institutional issues, a major concern is how to develop, flexible and adaptive institutions, legal frameworks, and problem solving mechanisms to allocate water among its competing uses.

Recommendations:

- Bridges are needed between information that can be produced regarding future climate variability and change and the information required to understand tradeoffs among different water management alternatives including reliability of climate information, use of hydrologic models to translate climate information into streamflow, water levels and soil moisture, and decision support systems.

• There is also a need for demonstration or pilot projects to assure appropriate linkages are made among water resources stakeholders, water system operators, government agencies, and the scientific community. The Global Water and Energy Cycle (GEWEX) Continental-scale International Project (GCIP), which is about to be initiated in the Southeast, is encouraged to undertake such pilot projects to accelerate the development of models and information related to the prediction of precipitation, soil moisture, and streamflow and to test their value to the water resources community.

• To better allocate water and resolve water conflicts, innovative supply side management (i.e., water credits, pricing strategies, inter-basin transfers, etc), integrated basin management using multi-governmental and stakeholder teams to solve problems, and flexible institution/mechanisms for resolving conflict are needed.

Agriculture

Findings:

• Agricultural sector in the Southeast is productive yet diverse both in systems (cropping and farming systems as well as diseases, insects, weeds, and pest-complexes) and stresses. Because irrigation is not as prevalent as in other parts of the country, the effects of climate variability and change on agriculture can be amplified.

• The heterogeneous nature of topography, soil structure and quality, and climate (e.g., strong ENSO signal) is unique in the Southeast. The interrelationships among these characteristics and their role in sustaining productivity is not well understood.

Recommendations:

• In the agricultural sector, a need exists to develop, validate, and evaluate new technology capabilities such as climate forecasting, use of remotely sensed data, biophysical modeling, and precision agriculture using a multidisciplinary approach that includes producers, researchers, government agencies, farmers and others in the private sector.

• In agriculture there is also the need to explore the transfer/communication of relevant information on climate variability/change over a full spectrum of temporal and spatial scales to users and user-specified applications. This may be best realized through the support of demonstration or pilot projects with the county extension system or similar outreach programs.

Urban Areas and Human Health

Findings:

• Air quality is a major concern of urban areas and it contributes to a host of environmental and human health problems (e.g., secondary air pollutants such as tropospheric ozone and chronic and acute respiratory diseases). These problems can be exacerbated by climate variability and change.

• Urban heat islands, land use changes, and urbanization in general directly contribute both to air quality degradation through their influence on photochemical processes and to the local and regional climate (e.g., elevated air temperatures, altered precipitation patterns, changes in surface albedo, etc.).

Recommendations:

• Data are needed to identify susceptible populations that will be affected by changes in climate extremes and variability, to correlate respiratory health to air quality changes resulting from climate variability, and to evaluate the cost of local and regional climate variability impacts on urban areas for urban planners and decision-makers.

• Improved education of both the public and decision-makers and effective communication by scientists to the public on the effects of climate variability and change on urban areas and human health and on how urban areas affect local and regional climate is essential in developing mitigation strategies.

Coastal

Findings:

• Populations on and near the coast of the southeastern US grew at phenomenal rates over the past 30 years leading to complex social and economic concerns related to mitigating the impact of climate variability and change such as sea level rise, storm surges, and extreme events.

• The potential range of climate-related impacts on ocean and coastal resources has been fairly well documented but a comprehensive assessment of the magnitude of environmental and economic costs associated with coastal impacts and hazards is still lacking.

Recommendations:

• Better compilations of life history data for coastal ecosystems and improved understanding of carrying capacities for sensitive species are needed so that managers can better understand the range of impacts and assess mitigative actions. These data need to be merged with socioeconomic and climate variables to improve our understanding of and ability to communicate the potential impacts.

• The current natural systems approach, which relies on biogeographical provinces, needs to be expanded to include climatic relationships. Further, various controlled-use sites (e.g., National Wildlife Refuges, National Estuarine Research Sites, LTERs, and LMERS sponsored by NSF) in the region should be linked to develop a baseline reference system for studying change.

Parks and Public Lands

Finding:

• Southeast region is forecast as the fastest growing in the country causing expansion of stresses on parks and public lands (introduction of non-native, invasive species, habitat fragmentation, island biomes, water and air quality issues), while at the same time, current fiscal conditions results in managers of public lands being stressed. Public managers are not well equipped to deal with extreme climate events and they have specific information needs related to decadal climate fluctuations, storm predictability, and extreme events.

Recommendations:

• There is a need to develop firm federal policy on infrastructure in public areas so as not to exacerbate or expand development pressures from outside the public area or create more fragmented systems.

• Regional cooperation among federal, state, and local agencies and the private sector need to be encouraged for maintenance of community continuity to allow for adaptive change in habitat/biological communities. Southern Appalachian Assessment (SAA) might serve as an example of multiagency cooperation for integrated planning and development of information for use in local and regional decisions.

Extreme Climate Events

Finding:

• Extreme climate/weather events have a considerable impact on stakeholders in the Southeast associated with sectors that include energy, emergency management, and water resources. The Southeast is becoming increasingly vulnerable to extreme events including hurricanes, floods, droughts, ice storms, heat waves, and tornadoes because of rapid population growth and development in vulnerable coastal locations.

Recommendations:

• There is a need to maintain and extend our ability to collect, analyze, and disseminate data related to climate over the long term. In the case of extremes, such data have a demonstrable relationship to decision-making. Given that societal and environmental problems associated with climate extremes are complex, data causes must also be collected on non-climate factors (i.e., social and economic impacts and causes).

• Bridge building must increase to develop processes to determine what climate information and tools would be of use to stakeholders. Existing organizations should be used to enhance the linkage between climate science and regional stakeholders.

Education

Finding:

• Since education cuts across each of the breakout topics, there are many opportunities for the educational community to contribute to the climate research agenda, to use scientific results to enhance educational programs, and to educate future generations of teachers to implement earth system science programs.

Recommendation:

- From the educational perspective, the most important recommendation is to promote the adoption and expansion of existing authentic learning programs, such as Global Learning and Observations to Benefit the Environment (GLOBE), that involve students and their teachers in data collection, data manipulation, and data interpretation. The upcoming Global Water and Energy Cycle (GEWEX) Continental-scale International Project (GCIP) in the Southeast was suggested as a candidate program for establishing a partnership between the scientific and educational communities to demonstrate this approach.

1. Introduction

The US Global Climate Change Research Program (USGCRP) and the Office of Science and Technology Policy (OSTP) are coordinating a series of workshops on vulnerabilities of various regions of the United States to climate variability and climate change. These workshops are expected to engage key regional stakeholders to identify and examine high priority regional environmental issues affected by current climate variation and climate change and to obtain information that can be aggregated across regions to support analyses of climate-related impacts and vulnerabilities at the national scale. The workshop on the southeastern United States, which was jointly sponsored by the National Aeronautics and Space Administration (NASA), the U.S. Geological Survey (USGS), and the National Oceanic and Atmospheric Administration (NOAA), was held at the Vanderbilt University campus in Nashville, Tennessee on June 25-27, 1997.

The purpose of the Southeast Regional Workshop was to examine the impacts of climate variability and potential vulnerability to future climate change on various economic sectors, with an emphasis on water resources, in the following southeastern states: Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, and Tennessee. The initial basis for this workshop was to develop better long-term dialogue between federal agencies engaged in climate-related research and key regional stakeholders who are responsible for the operational decisions of natural resources management for the purpose of demonstrating the value of federal earth science research for practical applications. This workshop focus was later expanded in accordance with the USGCRP and OSTP themes mentioned above to include an examination of the regional vulnerability in a broader range of potential impact areas such as agriculture, forestry, and human health to current climate variations and climate change.

The emphasis on how climate variation and climate change will influence hydrology and water resources of the southeastern United States, and in turn, how these changes may affect interests such as agriculture, forestry, water resource management, etc., was selected for several reasons. First, there is a relatively strong El Nino-Southern Oscillation (ENSO) signal in the southeastern United States that can be related to interannual variations in precipitation and temperature. Thus, any improvements in these ENSO forecasts in the future can provide significant economic benefits to farmers, utilities, and other natural resource managers in this region depending on their ability to use them effectively. Second, better forecasts of precipitation and temperature have enormous economic benefits to large power producers in the region including the Tennessee Valley Authority, Duke Power, and the Southern Company. For example, improved precipitation forecasts are estimated to save $2M over a five-year period for one southeastern utility. Also, better short-term (48-72 hours) temperature forecasts offer significant economic benefits to utility load management decisions. As the nation’s utilities move toward a more competitive environment, such forecasts will become invaluable. These potential economic benefits, however, are related not only to better forecasts but also to improvements in how water and energy resources managers use these forecasts. Finally, the southeastern United States has suffered over the years from extreme climate events including hurricanes, tornadoes, lightning, and winter storms. A better understanding of climate and weather data, and the application of this information to private and public sector decisions on disaster prevention and mitigation could have significant benefits for society.

In addition to the economic implications of climate variability in the Southeast there are also scientific considerations for emphasizing hydrology and water resources, and their influence on various economic sectors. For example, beginning in 1998 the GEWEX Continental-scale International Project (GCIP), a study of the Mississippi River Basin intended to improve scientific understanding and to model on a continental scale the coupling between the atmosphere and land surface for climate prediction purposes, will focus its attention on the eastern part of the basin - namely the Tennessee-Cumberland and Ohio River Basins. One aim of these intensive studies is to generate inputs for operational hydrologic and water resources management models for use in local level decision making. Other major ongoing studies in the Southeast such as the EPA's Gulf of Mexico Program and USGS's National Water Quality Assessment Program also provide the scientific underpinnings for the workshop focus.

During the workshop four basic themes became apparent. First, the regional infrastructure in the areas covered during the breakout discussions is already being stressed by near-term weather and climate variations. In addition, meeting current day-to-day operations consumes most of the time and budget of a regional stakeholder in the absence of climate-related issues. If the magnitude of climate variability increases or there are more frequent extreme events, the system will be stressed even further. Incorporating climate variability and change into these operational decisions will only exacerbate this situation.

Second, although our climate predictive skills are improving, especially with short-term forecasts (i.e., up to 72 hours) and data are currently available or are emerging from the climate community, these information are not widely used or understood by the regional stakeholders. In essence, there has been an inadequate communication of climate risk at the regional and local levels. Decision-makers at these levels want additional information on climate variability and change if they can obtain answers to questions about the magnitude of effects, the timing, and the potential costs. Given the inherent uncertainties in recognizing climate change against a background of normal climate variability, regional stakeholders must decide in a world of considerable uncertainty. The workshop intended to highlight some of the new approaches and new data emerging from the climate community. It is anticipated that this workshop and any follow-on efforts will help mold these approaches and data for better use by the stakeholders.

Third, regional stakeholders are generally unable to effectively use information, data, and products that are currently available from the climate community. A clearer understanding of the products that are available or will be available in the near future from the scientific community is greatly needed. Furthermore, individual scientists performing research are not generally expected to negotiate and communicate their results directly with the policy- and decision-makers. An exerted effort will be required to identify scientific results that can be used in the public and private sectors and can contribute more directly to near-term economic and societal applications. One cause of the current deficiency is that existing delivery or distribution systems (e.g., county extension programs for agriculture) are not generally linked to the outputs of the climate community.

Fourth, stronger partnerships among federal and academic researchers, regional, state, and local stakeholders, and the private sector are needed to adopt and incorporate advanced science results, technology, and data products into everyday decision-making. Better linkages are required between researchers and regional stakeholders to define better the needs of a broader user community and to identify scientific results that will meet these needs. The use of selected pilot studies that demonstrate this approach is strongly encouraged.

The workshop was highlighted by several key presentations including Vice President Al Gore, Mayor Bill Campbell of Atlanta, Dr. Jack Gibbons, the President's Science Advisor, and Dr. Jerry Melillo from the Office Science and Technology Policy. Several plenary talks set the context and framework for the breakout session discussions (see Appendix A for the workshop agenda). The topic of climate was framed by Dr. Jim O'Brien of Florida State University, who demonstrated the enormous effect that El Nino and its opposite El Viejo (La Nina) has on the climate variability of the southeastern United States. In addition, Robert Quayle of the National Climatic Data Center, discussed observed climate trends for the globe and the Southeast. Dr. Roger Pielke, Jr. of the National Center for Atmospheric Research organized a panel of scientists and stakeholders representing agricultural, coastal, and energy interests on climate extremes and societal impacts. Many of the regional stakeholder perspectives were outlined by Dr. Michael Helfert, head of the Southeast Climate Center in South Carolina. Finally, Dr. Roger Bybee, National Research Council, offered insights on the educational aspects of climate. Extended abstracts of these plenary talks are presented as part of this summary.

The breakout sessions were focused on important economic sectors including: agriculture, coastal and fisheries, education, extreme events, parks and public lands, urban areas and human health, and water resources.

The following four questions were posed in each of the breakout sessions:

- What are the current concerns and stresses of the regional stakeholders in each sector?
- How can current climate variability and climate change amplify these concerns and stresses?
- What information and data is needed to address these climate-related issues?
- What types of strategies and approaches are available for coping with or mitigating these stresses?

The responses to these questions, which served as points for discussion within the breakout sessions, are the major output of the workshop. In this summary, we next provide extended abstracts of the various plenary talks followed by the full set of findings and recommendations representing the deliberations of the seven working groups and the final, plenary session. These findings and recommendations warrant serious consideration in future national assessments of climate impacts. However, there are gaps in the areas considered at the workshop, especially for forestry, fisheries, and freshwater ecosystems. These gaps will be addressed in future workshops and discussions.

There is much more to learn about the effects of climate variability and climate change on the key economic sectors in the Southeast. The findings and recommendations of this workshop provide a beginning discussion on what is important and how to proceed. It is expected that these recommendations will be reviewed and updated at regular intervals. In this way, we can better prepare for an uncertain future.

2. IMPACTS OF ENSO GENERATED CLIMATE VARIATIONS IN THE SOUTHEAST UNITED STATES

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Introduction

The Planet's earth, air, water, ice, biological system experiences climate variability over many time scales. As humans, we are acutely aware of the diurnal and seasonal time scales. Persons who are fortunate to travel discover the effect of latitude on the range of air temperature and precipitation on these daily and annual signals. Folks who talk to grandparents or live past 40 years' experience interannual variations, i.e., "last winter was the coldest, I have experienced"; we never had a hurricane as long as I have lived in this town," etc.

When the author was studying to be a chemist at Rutgers, all these interannual events were blamed on Soviet bomb tests in the upper atmosphere. As recent as the early 1960's, geophysicists predicted an ice age and people were talking about moving equator- ward. Now the tabloid presentations of Global Warming impacts have people considering moving inland and poleward.
Scholars have found that there are other potential short term variability events such as 5 - 10 year or 10 - 20 year natural variability events such as the dust bowl in Oklahoma in the 1950's, the droughts in Texas in the 1950's, the lack of hurricanes in the 1970's, the drought in the Sahel in the 1980's, etc.

In the 1960's, El Niño was discovered but except for some oceanographers who worried about anchoveta stocks off Peru, the climate variability caused by El Niño in all the Pacific Rim countries and other far away places like southern Africa, India, etc. were not studied. El Niño means warm water (+1.0 degree) along the equator west of the Galapagos Islands in the Pacific which lasts for five or more months. El Niño occurs every 3 -7 years. The climate variations created by El Niño over North America are substantial as will be discussed below.

Recently, climate scientists were investigating some "new" phenomena, such as the "North Atlantic Oscillation" as a creator of both 2 - 5 year and 18 - 25 year climate variability.

All in all, upon reflection, we can identify time scales of climate variability from day, season, year, interannual, decadal, multi-decadal and longer. Unfortunately, we do not have the climate records to study longer time scales and we resort to the marvelous fingerprints of climate variability in trees, fossils, ice, mud, etc.

In fact, in the southeast, we are experiencing a slight cooling over the past tens of years. The main point is that climate variability occurs on many time scales. Our climate records are very short. In the southeast United States, we have very few stations more than 150 years long. This means that we have not experienced the outliers in a NORMAL stationary climate record. We must really expect to experience hotter, colder, wetter, dryer weather than ever measured before. A few years ago, everyone in Tallahassee was commenting on a drought near the end of the year because we had 15 inches less rainfall during that year. Some blamed the event on global warning or the new high magnetic fields produced at Florida State University which pushed the rain away. In fact, such a deficit should occur about every 12 - 14 years. An inspection of the climate record for Tallahassee indicated this was true, but everyone has too short a memory.

The economic impacts of climate variability are vast. The impacts on food production, energy, fisheries, recreation, etc. are enormous. We are gradually learning about climate variability and how to anticipate climate variability. We need to learn to forecast climate variability and bring these understandings and prediction to the stakeholder level.

Climate Change

There will certainly be global climate change and regional climate change. The increase in human population, the change of land use and many other man-created changes will affect climate change. Some will be permanent changes. The emission of radiatively-active gases such as CO_2 and methane have a radiation interaction with the atmosphere and increase the greenhouse effect. Whether we get warming from CO_2 or cooling from a coming ice age, is not as important as identification of the cause and magnitude of climate variabilities.

The existing record shows an increase of 0.5°C in the globally-averaged surface air temperature more than 100 years. Is this signal a remnant of the difference between warming and cooling or is it a part of a 200-year long variability?

In the southeast United States, the largest cause of climate variability is El Niño and its counterpart (Mr. Hyde), or "El Viejo," the scientific term for a cold ocean along the Equator in the eastern Pacific Ocean. After one subtracts the diurnal and seasonal signal from the climate record, then floods and droughts, heat waves and ice storms, more or fewer hurricanes, more or fewer tornadoes, etc., in the southeast United States are directly linked to the occurrence of warm or cold water in the Pacific Ocean west of the Galapagos Islands.

Hurricanes and Things

The biggest single effect of the number of hurricanes to strike U.S. landfalls (almost all in the southeast) is El Niño. If there is warm water in the eastern equatorial Pacific, the probability of 2 or more hurricanes striking the southeast United States is *one in every five years*. If the ocean water is not 0.5°C warmer, the probability of two or more hurricanes striking the southeast United States is *one in every two years*. Hurricanes and tropical storms are a major source of fresh water for most of the southeast. Unfortunately, they do lots of damage when striking popular coastal regions. Recent studies have shown that the incredible increase in damage due to hurricanes is not due to global warming, but due to the fact that more people live in the coastal zone.

The increase in the number of Atlantic hurricanes in the 1995 season was due to El Niño going away. The large number was natural variability. The Insurance Industry asked the author to discover whether global warming would mean more Atlantic hurricanes. A study by the Max Planck Institute shows that warm ocean in a CO_2 doubling experiment is similar to a semi permanent El Niño and, thus fewer hurricanes in the Atlantic.

Unfortunately, there will be more intense Pacific hurricanes (the kind that strike Hawaii or Mexico) and more typhoons for Asia. (After all, the Planet general circulation must have hurricanes to transport the heat poleward to high latitudes and tropical storms are very efficient to accomplish this.)

The conclusion is, if we have more global warming, there will be fewer hurricanes for the southeast. We need to calculate how much loss of water for the Carolinas, Georgia and Florida. On the other hand, a recent study by Cane, et al. indicate that the 100-year SST record in the Pacific shows more El Viejo or cold events. This means more Atlantic hurricanes!

What is going on? The models are not good enough! Maybe! The coupled ocean ice-atmosphere models show warming when one increases the CO_2, but the ocean in the

Pacific shows cooling and the minimum temperatures in the southeast United States show cooling.

El Niño is a Good Dude

El Niño is a wonderful positive climate happening for the southeast United States! El Niño suppresses hurricanes. El Niño gives winter rain to the coastal Carolinas, the State of Florida and the coasts of Alabama, Mississippi, Louisiana, and Texas. This greatly suppresses forest fires, helps winter vegetables, produces better oranges. And, nicely, it is only a "bit of extra rain," so it does not hurt tourism.

The opposite of El Niño is called "La Niña" by some scientists, "El Viejo," by COAPS, and more properly, the cold phase of ENSO by the educated scientific community. El Viejo is very bad for the southeast United States. We have more hurricanes, winter droughts in the coastal regions of the southeast, and therefore, raging forest fires. But there is a newly discovered serious climate variability problem. When El Viejo is alive, near the Galapagos Islands, a new tornado belt exists from Mississippi to Indianapolis. In Tennessee, the probability of four or more tornadoes occurring in the spring (March, April, May) when El Viejo has occurred in the winter is 4 - 5 times more likely than other years. This recently discovered fact arose from studying climate variability and not secular trends.

The Future

There will be an alarming climate change in the southeast United States due to growth of population, and, accompanied land use changes. On the bright side, oceanographers and meteorologists are learning how the ocean controls the climate variability on daily, seasonal, interannual and decadal time scales. If we learn to educate the stakeholders on the new scientific knowledge and the new ability to forecast these events, a great economic benefit will be achieved.

A Gift

A video of the animations I showed in my talk was made. You can have a copy by emailing me at OBRIEN@COAPS.FSU.EDU.

3. Observed Climate Trends for the Globe and the Southeastern United States

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The Intergovernmental Panel on Climate Change has concluded that man may indeed have begun contributing to the Earth's process of climatic change. Probably with help from an enhanced greenhouse effect, global average temperature has increased by about half a degree Celsius over the past century and is predicted to rise further and raise sea level (see Fig. 1). The southeastern U.S. is one of the handful of places on Earth showing a net cooling over the 20th century (see Fig. 2). This is not entirely unexpected, as some climate model simulations show a tendency toward reduced warming in the eastern U.S. due to anthropogenic sulfate aerosols. U.S. precipitation has also increased, in general agreement with model projections that as the globe warms, mid- to high-latitude precipitation will increase. Nationally, most of this increase has been in the more extreme events, and very little in the more moderate events (see Fig. 3). While moderate rains generally benefit agriculture and the water supply, heavy rains are less efficient (more water runs off into the sea), and are more likely to cause flooding. And, with a climate warming, it is also likely that there will be increased drought frequency. This strange combination of generally increasing precipitation interspersed with increased drought frequency is exactly what the Southeast has experienced during summer in recent decades.

Fig. 4 shows regional model predictions of changes in precipitation median intensity for the 48 contiguous U.S. This experiment was run to estimate the likelihood that observed precipitation trends (generally toward more intense events) would continue. For most areas an increase in heavy precipitation is evident, while the median is relatively unchanged. This experiment used two 20-year simulations, one consisting of a control run with today's carbon dioxide, and the other a series of runs with doubled carbon dioxide. The difference between today's precipitation climate and the climate with doubled carbon dioxide was calculated and mapped for 9 U.S. regions and the contiguous U.S. as a whole, with the overall mean of all 9 areas plotted to the right off the SE coast. Because of the increasing precipitation intensity, increased flooding, runoff, and erosion are quite possible in a greenhouse enriched atmosphere.

Climate has changed many times in the past, but the current rate of change seems to be large and there are enough similarities between observed changes and expected changes due to increased greenhouse gas that most scientists now believe that the evidence for man's impact on climate is compelling. While there is still uncertainty, the primary concern has shifted from the question "Will climate change? to the question "What will be the nature of the impending climate change, and most important, what will be the consequences?"

List of Figures:

Fig. 1. IPCC 1995 projections of a) global warming and b) sea level rise (after Houghton et al., 1996). The shaded area represents spread between the smallest projected warming & sea level rise (dashed line, assuming stabilization at 450 ppmv carbon dioxide in 2100), and the largest warming & sea level rise (solid line, assuming stabilization at 650 ppmv carbon dioxide in 2200).

Fig. 2. Mean annual temperature and precipitation trends for the globe based on data collected from a variety of sources. Closed dots (positive trend) depict warming or

moistening, and open dots (negative trend) depict cooling or drying. The size of the dot is proportional to the trend (in degrees C and % per century) as noted on the Figure. The period of these data is 1901-1996.

Fig. 3. Past precipitation trends (% per century) regionally for the contiguous U.S., for various percentiles of daily precipitation. To calculate these, daily precipitation amounts for all days of each year-month were arrayed from the lowest to the highest, and the threshold amounts calculated for all precipitation events falling in 5-percentile increments of successively increasing precipitation intensity, (e.g., <5%, 5-10%, ... >95%) for each month, season, and year. The yearly precipitation amounts for each category of precipitation intensity were then subjected to time series analysis, and the resulting linear trend expressed as the precipitation change per century in each interval as a percentage of the overall total mean precipitation. The period of record is 1910-1995. This diagram shows the contribution of various precipitation class intervals to the total increase of precipitation during this time of approximately 10%.

Fig. 4. Goddard Institute for Space Studies (GISS SI95) global climate model predictions of: (a) the percentage change in the proportion of total annual precipitation from 1-day events over 1 inch; and (b) the change (in mm) of the median 1-day precipitation amount. Closed circles depict increases and open circles depict decreases.

4. Trends in Extreme Events and Societal Impacts

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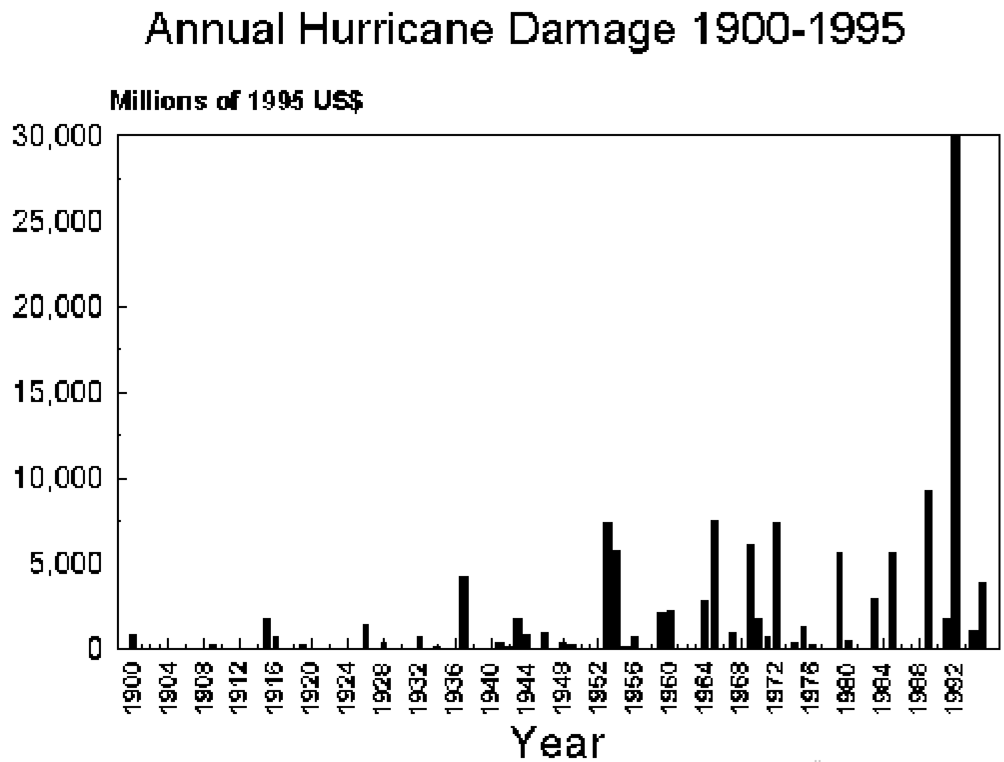
> We do not know. . . for sure that the warming of the Earth is responsible for what seems to be a substantial increase in highly disruptive weather events, but many people believe that it is, and that we have to keep looking into it. . . If there is a larger cause which can be eased into the future, we ought to go after that solution as well.
>
> President Bill Clinton, April 22, 1997

The recent statement by Present Clinton reflects two common perceptions. First, it reflects a sense that the economic impacts associated with extreme weather events have increased in recent years. Second, a perception exists that the recent increase in weather-related events is due to changes in climate related to global warming. In recent years, these perceptions have resulted in almost every extreme event being attributed, by someone, to global warming.

The perceptions are more than simply idle speculations -- they underlie policy decisions with important social, economic, and political ramifications. For instance, in December of this year representatives from nations around the world will meet in Kyoto, Japan to discuss and debate implementation of the Framework Convention on Climate Change. Because policy is based on the perceptions that policy makers hold about climate, it is worth determining the validity of the two perceptions.

In the case of economic losses associated with extreme weather events (specifically hurricanes, floods, and tornadoes), there is a trend of increasing losses in recent decades in the United States. Thus, the first perception is demonstrably valid. There is, however, no reliable evidence to date to support the perception that recent trends in economic losses in the United States are attributable to changes in climate -- *regardless of the hypothesized cause*. Clearly, climate has varied regionally with respect to particular phenomena, however, this variation is difficult to discern in the historical record of societal impacts (e.g., dollar losses). Instead, the strongest signal present in the historical record is that increased societal vulnerability is the primary cause of recent increases in documented economic losses. Note that this finding in no way refutes the global warming hypothesis. Rather, it refutes the claim that past losses can be attributed to the increased frequency or magnitude of extreme weather events. This is consistent with the findings of the Intergovernmental Panel on Climate Change, published in 1996.

The two attached figures show trends in hurricane damages during this century. Figure 1 shows the data for 1900-1995 adjusted only for inflation. Figure 2 shows the data “normalized” to 1995 values. That is it presents what damages would have been had each hurricane season occurred in 1995, based on inflation, increased wealth, and population growth. (A full copy of the paper is available at http://www.dir.ucar.edu/esig/HP_roger/hurr_norm.html.) The analysis shows that for hurricanes, increased losses are driven by societal changes, and not climate changes.



Source: Herbert et al. 1996

Figure 1. Time series of United States hurricane-related losses (direct damages in millions of 1995 U.S. Dollars) from 1900 to 1995.

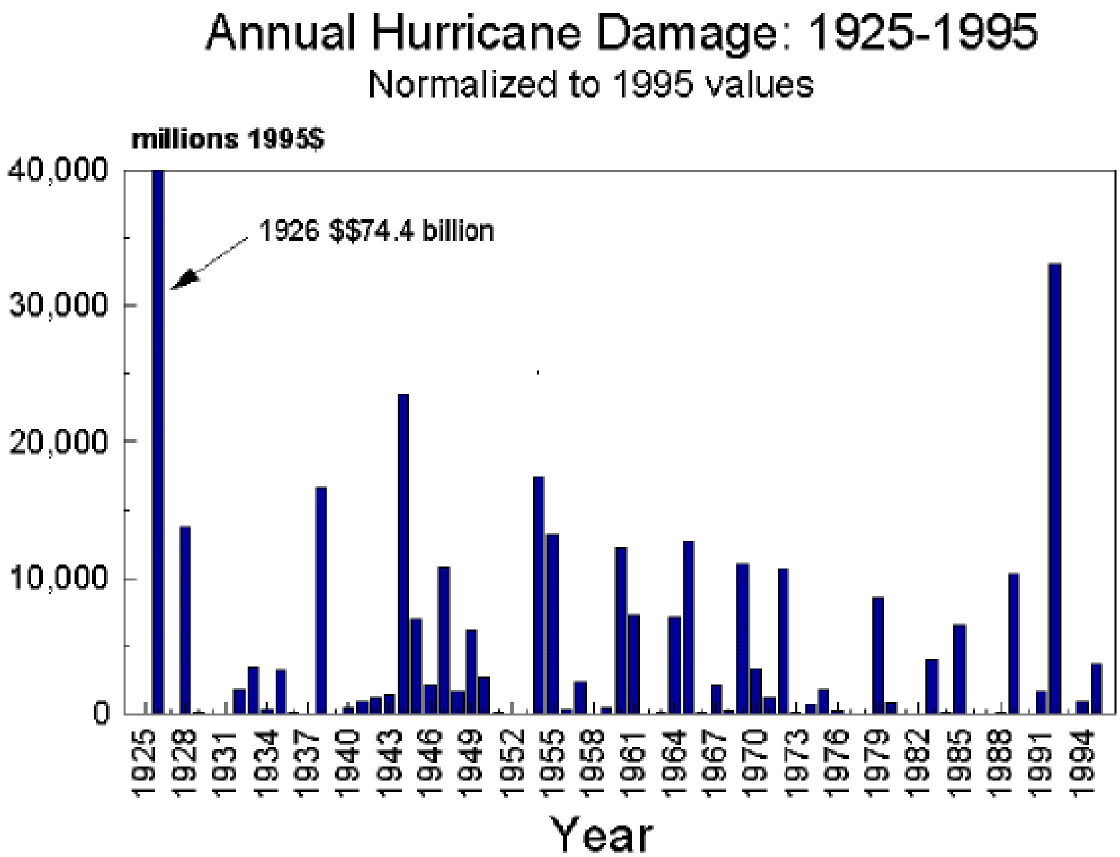


Figure 4. Time series of United States hurricane-related losses (direct damages in millions of 1995 U.S. Dollars) from 1925 to 1995 in normalized 1995 damage amounts (utilizing inflation, coastal county population changes and changes in wealth).

5. CLIMATE VARIABILITY IN THE SOUTHEAST UNITED STATES AND ITS POTENTIAL SOCIETAL IMPACTS

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There is little doubt that global warming is occurring in the 20th Century, and that it is occurring due to anthropogenic emissions. The most objective and most comprehensive of the several scientific analyses concerning recent changes of climate indicate strongly that an increase of the average global temperature has increased about 1°F during the past century. A further minimum increase of 1-2°F should be planned for in the lifespans of our children and their immediate children. It is possible that an increase of up to 6°F during the same time frame if our species modifications of the Earth's atmosphere constituents and transparency do not decrease or stabilize.

The primary causes of OUR global warming are increases in the discharge of greenhouse gases, particularly carbon dioxide, from industrial processes, energy consumption patterns and practices, agricultural inefficiencies and practices, forest conversion and biomass burning . In the Southeast U.S., we do not contribute to all these imbalances in an equal way - nor do we redress these ills when recognized in necessarily logical or scientific ways. Like the other regions of the U.S., we have too many cars, too much air-conditioning and other artificial environmental contrivances, too much wealth and too much consumption, and a rather profligate attitude towards time, space, and the environment. In reality and in generality, this is but typical Americana - societally irresponsible and genuinely immoral. In the end this will change, but only at the point of Reality.

Equally as environmentally distressing and equally as immoral as the behavior of our American society on a finite planet subject to both physical and biological limits are similar activities in other regions - whether the excessive consumption of Western Europe and Japan; the excessive consumption of low-quality fossil fuels in China, India, or Russia, or the landscape burning that typifies the Southern hemisphere in particular.

The yearly conversion to other uses of 35-50 million acres of former tropical forest has had at least a selected regional climatic impact directly through seasonal and multiyear albedo changes and carbon capture in Africa, Latin America, and South/Southeast Asia. These albedo differences are so marked from space that I use national boundaries as landmarks to teach astronauts and cosmonauts where they are over the face of the Earth. Burning from Southern Hemisphere and equatorial latitude forest conversions has formed 2-4 month duration smoke palls each year since the early 1980's. These smoke palls are so pervasive that they have their own seasonal names in Latin America, that they have interfered with air transport between the Philippines, Malaysia, Indonesia, and India (usually during El Nino years...), that they impinge upon general biotic health in the underlying areas, and that we have documented them at sizes approaching that of the continental United States with multi-monthy persistence.

In the observations of the Shuttle and Mir astronauts and cosmonauts, the Amazonian smoke pall alone stretches from north of the Equator to the Falkland Islands and the fringes of the Antarctic. Largely still unrecognized is the importance of both seasonal and multiyear regional albedos due to such forest conversion programs in the tropical latitudes.

Likewise important to regional-scale changes of albedo and likewise visible from space are the air-pollution smog of the Eastern United States stretching from the Mississippi-Ohio River Valleys east to Bermuda and perhaps Iceland (somewhat euphemistically known as "hazes"), China, Russia, India, and the great megacities worldwide. No city of 5 million souls or greater appears to be immune no matter how well ventilated. Perhaps this will be a limit on the size of our conurbations if we graduate to a more civilized future?

Now, it would be most productive to graduate from the regional or national finger-pointing stages of problem recognition to integrated problem mitigation. Can it be done? Yes, it can. But only after education of not just the policy makers and the general public, but also after unification of the opinions and noise of the science community.

We aren't there yet. And time is slipping away. Listen up. My PRIMARY PURPOSE AT THIS CONFERENCE IS NOT TO LECTURE TO YOU OR AT YOU, but rather to LISTEN TO AND INTERACT OR NETWORK WITH YOU.

As a TV lady of some directness has questioned: "Can we talk?" If so, I will give you some regional background and unregulated concerns that I have. Let's go from there.

My observations on regional concerns in the Southeast are based upon not only upon my global observations as a teacher of astronauts, but also by my analysis of the two million inquiries received per year by our small center from the state and local governments in Virginia-the Carolinas-Georgia-Alabama-Florida-Puerto Rico & the Virgin Islands; from various COG's; from private sector meteorologists whom we support, from various Federal agencies; from local Chambers-of-Commerce; from taxing authorities of various scales and charters; from the legal, banking, and insurance industries throughout our region; from the construction, engineering, planning, transportation sectors; from the forestry, agriculture, silviculture and aquacultural concerns in the Southeast; and from the general public throughout the South and Southeast.

These inquiries represent two million questions of climatic concern per year from these people and from representatives of the people. Let me mention that, for this conference, I have also been asked to represent the Southern Regional Climate Center located at Louisiana State University in Baton Rouge, Louisiana, which services like inquiries for climate data and information for Texas, Oklahoma, Arkansas, Louisiana, Mississippi, and Tennessee. Similarly, the other four Regional Climate Centers: the Midwest, the

Northeast, the High Plains, and the Western United States -also address about 16 million other inquiries all told each year.

My given charter is to represent the regional interests or "stakeholders" for the Southeast United States in getting the National Government to listen to us in the Southeast. In turn, we need to listen, question, and derive information from Federal sources that may be useful to us at the local, state, and regional levels so that we may form our own judgments. Thus, it is apparently hoped that our democracy will at least have a feeling that there is governance "by consent".

That charter is difficult given that the National Government has a strong history of poor and indirect Telling and some of the States have a habit of Yelling. In the most extreme case of Federal Deafness and State Hollering, this has led to a circumstance of what is still known in our region as The Recent Unpleasantness.

Hopefully, our discourse has grown a wee bit more mature over the past 135 or so years. Therefore, I sincerely doubt that such a situation will prevail in the 21st Century - which is advancing with more certain velocity than even the postulation of a Congressional decision of real gravity or merit.

The problem of global warming is bigger than all of our governmental constructs, or our historical attitudes and misconceptions, much less the past realities than our forefathers have had to deal with - at least since the Little Ice Age in the middle and higher latitudes of the Northern Hemisphere. That was a period of a wee bit of a chill, not a "warming". Additionally, that earlier time was not marked by a technological or energy-rich society that was interconnected on a global scale. The situational parallels are therefore not parallel - biologically or ecologically, physically, or societally.

Let's drop the foo-frah-rah for a moment here. Why are we here? Where are we going? What are our objectives? I am of the opinion that we are only in the definition phase, and that we need periodic vice a periodic informational briefings and strategy assessments and modifications in order to maintain a sensible and progressive societal temporal tree.

I doubt that this conference should be viewed as more than a start position in problem and program definition, and of even more import, as only a start in a meaningful and objective dialogue between and among the parties who construct our REGION. If this meeting is a one-time administrative burp to allow the checking off of some bureaucratic box then this is a farce, and we are all wasting our time.

That position gives us a clue as to what we should question here. We need to take control; we need to enunciate our needs and positions; the Federal guys need to listen. The real question is not identifying the regional stakeholders. Every person in this region is a stakeholder.

Rather our question at this conference and in this review stage is identifying just WHAT are the regional stakes. This should be done in each of the following sub-discipline meetings.

This has to be done at such a level that every citizen and every governance level will voluntarily and energetically understand the implications of Non-Change at both the individual and societal levels. That may be a more successful tactic in educating our society to change than to state the desired changes that MUST be made. My teenagers only listen, think, and act in desired ways when they are empowered; not when they are dictated to. It is the same with the American psyche as a whole.

It is therefore a question of education; it is a question of both individual and social responsibility; it is a question of providing for and caring a recognizable and desirable future; it is a question of participation in governance.

With that philosophical introduction, and with my desire to provoke to discussion, and thence to action, let me now go to a survey of the regional implications to the U.S. Southeast of global warming. We can euphemize and say "climate variation", but let's not play-act - let's do.

That involves moving beyond the premise of global warming and perpetually and tiresomely arguing its presence or absence or non-velocity or non-causation based upon an ego agenda or political agenda or the comfy confines of some non-participatory reality or academic tower.

We can't afford that luxury here. Let's get to work.

OK. Where to start?

What is our regional stake? Easy. UNCERTAINTY and thus changes of our habits, our expectations and perceptions, even our derivations of Futures.

More specifically - Given: Climate Change is occurring. The Climate Change that is occurring is global warming.

FAULT IS NOT THE QUESTION; MITIGATION IS.

Thus we have the question; the position; and the attitude. Anomaly: Of all the places on the face of our small planet Earth (with a big E) that are being impacted by climate change, one of the few places that is thus far benefiting is the Southeast United States, where we are having a small regional climate cooling. That makes it hard to sell "global warming" on a regional basis where cooling is measured.

Unfortunately our luxury may only be a small temporal blip before we too are impacted as is already the case in the U.S. Southwest, in South Africa, in India, in Australia, in portions of Russia, or in the Indo-Pacific. Probably the first thing that we notice will be a minor rise in our mean sea level. That is a very sneaky impact.

Changes of concern to our region are of two classes:

Internal (social and economic): We have become an even more energy-dependent society; we have become more isolated from our physical realities; we have migrated and continued to migrate to the areas of greatest exposure to climate risk - the river bottoms, the water, the coasts; we continue to involve towards mega-cities that are verily dependent upon resource hinterlands that are not sustainable; we continue to make babies with the assumption that biology does not have to respond to physics. These are not very intelligent societal situations. They assume that stasis is evolution. We will pay the price of our deliberate ignorance. Soon.

External (physical, chemical, and biologic): Global warming is here. We are but seeing its beginning. With global warming is coming the need, in our environment for a complete replanning of hydrologic systems - the availability, patterns of use, and replenishment of water resources and resource systems. New housing will be needed, new transportation systems and arteries to handle our influx of population, new energy planning and installations and systems for energy production and distribution, and we must have new general awareness- many of them centered around our relationships with water.

Immediate changes that we need plan for are new diseases and new disease vectors, new susceptibilities to disease due to changes in our immune systems. Additionally, I can foresee lowered air quality below even that already so prevalent for the United States east of the Mississippi. Our present region air quality is so bad - in reality - that from space in the autumn it is sometimes impossible to tell if one is over North America, the smoke-filled Legal Amazon Basin of someplace South America, a dense Saharan duststorm seemingly lost over the extreme Western Pacific Ocean, or the smog-covered Western Atlantic Ocean downwind of North America.

We are looking at the future where the application of sun-screen is an individual automatic action prior to going outside; what a gardener plants in one's garden or lawn is quite foreign to his or her family history; where the daily commute is different in form, time, distance, and complexity than anything that has come before; where leisure activity is a prioritization and balance of risk and reward; where diet changes and qualities must be accepted; where education must be viewed as a lifelong, personal responsibility; where social discipline is more required than is now acceptable in our small society; so here we physically live or do NOT live has to be a responsible choice of both the developer and the individual; where we must interact with and be aware of our neighbor - at various levels - for more than is now either the habit or the need. This is extreme news.

Cities such as Atlanta, Savannah, Jacksonville, Miami may be untenable in the near future without interbasin water transfers such as have become habit in the Intermontane or Cadillac West. An alternative may be desalinization or reverse osmosis or something not yet thought of. Water is a limit. Water will be a husbanded resource in those areas where "development" is still a goal.

Even Nashville is likewise pushing its foreseeable limits of quantity and quality given its most probable climatic and demographic futures. None of us will any longer have the ideal and habitual luxury of freedom of ignorant action nor individual environmental irresponsibility in the systematically interconnected and more fragile future. I'm sorry - it just does NOT compute.

Rainfall patterns are already most likely changing with a new pattern of regional climate warming. We are getting more events of more rainfall all at once, and fewer small events. Our total is remaining about the same, but the character of our wetter and drier seasons is already changing.

Of even more interest to the Southeast precipitation change cause is a question from far away. The atmosphere knows no political or regional boundaries. It goes where and when and how it darn well wishes to go. In this instance of finding a cause for precipitation changes in our region, the question is one of warming and mounding of seawater over the shallow shelf seas of the Western Pacific Ocean, of all places.

Let us look at this last point a bit more closely. This mounding and warming of Pacific Ocean seawater causes a periodic pulses of warm water to be sent outwards resulting in global and regional climatic anomalies (large Kelvin pulses or Kelvin waves) to be sent out bimodally - that is, both to the west towards Africa via the Bay of Bengal and the Arabian Sea, and to the east to the Gulf of Panama, the southern California Current areas, and the coastal currents of Peru and and Chile. Why the mounding occurs at all is a potential, still largely unaddressed base question for climatology.)
A second base question that is worthy of investigation in climate studies is how many El Ninos must occur before we recognize that the global climate system has changed? What is awry in the Pacific that we need understand for our own regional welfare? What are the implications of El Nino changes upon summer and winter rainfall patterns in the Southeast U.S.?

We are standing here today while watching on the tube 22 new additional feet of water backed up behind the spillway of the dam at Lake Travis, Texas upstream from the capital city of Austin in late June. Two days of rain in June did that. In Central Texas, that is big news - the last time it did that was during the El Nino year of 1957.

In Australia, they are shooting cattle today in order to not have to feed them when the 1997-1998 El Nino finally reaches such a level of crisis that the American media will finally notice. Our turn is coming in a couple of months.

Think about it. We are having the fourth or sixth year of El Nino effects of one level or another occurring in the seven years of this decade. Such a frequency of warm water in the Pacific impacting our regional and global climates has rarely occurred in the instrumental (1876 to the present), the historical (c. 1530 AD for the Americas; c. 1200-1500 BC for Southern China), or the known archeological records (c. 2500 BC). The delicate outdoor pre-Incan chalk drawings of the Northern Atacama survived until the 1925 El Nino washed them away. Likewise the deep guano deposits on the offshore islands that were traded away as fertilizer for English gardens in the 1870's, would have most likely not have otherwise survived past the rains of1982-83 El Nino.

In the earlier records, El Nino years usually have occurred every two to seven years on the average. Any new pattern of increased frequency, if that is what it is, may well be a strong sign of global warming.

For the Southeast, another El Nino is good news. It brings us more rain; it reduces temperatures; it provides more generally amenable growing conditions; it reduces the number of Atlantic Basin hurricanes below forecasted levels.

As an example of El Nino benefits to our region, Florida is in danger IF a future pattern of more frequent El Ninos does NOT occur. That is, the population growth and concentrations of humans are already beyond advisable levels. Florida is a climatic disaster based upon the old normals of water resources, of extreme climatic events (tropical cyclones) that is waiting to happen. In Florida, climatic exposure or risk is already beyond the advisable limits of the insurance or lending industries. To evacuate Dade County and the Miami region in advance of a hurricane will take about three times more time than is available from the present warning capability.

Now a few vu-graphs illustrating some few of our problems and of the climate impacts of a global warming trend in the Southeast. These are:

1. For vu-graphs of the Southeast Regional Climate Center Home Page, you are directed to: *http://water.dnr.state.sc.us/water/climate/sercc/dat_prod_serv.html*

2. Specifics on the climate, climate trends, and climate history of the Southeast (Virginia, the Carolinas, Georgia, Alabama, Florida, Puerto Rico, and the Virgin Islands) may be accessed through: *http://water.dnr.state.sc.us/water/climate/sercc/historical_data.html*

3. For vu-graphs of the State Climatology Office of the State of South Carolina, you are directed to: *http://water.dnr.state.sc.us/water/climate/sco/index.html*

4. Specifics on South Carolina climate, climate trends, and climate history may be found through: *http://water.dnr.state.sc.us/climate/sco/climate_sc.html*

5. Further information on the El Nino and the Southeast may be found through: *http://water.dnr.state.sc.us/water/climate/sercc/el_nino.html*

6. CLIMATE IMPACTS - MAJOR FINDINGS AND RECOMMENDATIONS

a. Agriculture Sector Findings

Jim Jones, University of Florida
David M. Legler, Florida State University
Gerald F. Arkin, University of Georgia
James W. Hansen, University of Florida

Nature of the Problem

Agriculture has been called "the most weather dependent of all human activities" (Oram, 1989). Because of this dependency, variability of climate from year to year results in uncertainties in agricultural production and risks to the well-being of farmers, to local and regional economies, and even to global food security. One reason that climate variability is so devastating to agriculture is that we do not know when to expect favorable or unfavorable weather. Many critical decisions must be made several months or seasons before the impacts of weather are realized, putting at risk large investments in resources applied to the crop. There are many recent examples where drought, floods, and freezing temperatures have resulted in total or partial failure of agricultural systems in the SE USA and other regions and countries. Agriculture's vulnerability to weather variability is expected to increase as the world's population increases and marginal lands are brought into production (Glantz, 1994), and as other sectors (urban, industry, recreation) grow and compete for land, water, energy, and other natural resources. In addition to year to year variations in climate, indicators highlight a contrarian trend toward cooler temperatures in the SE during the past century. Evidence also points to more frequent occurrences of extreme precipitation and thermal events in the US (Karl, et al. 1996). Changes in the global climate are expected over the next 50 years as atmospheric CO_2 and other greenhouse gases increase (IPCC, 1990a). Although the magnitude of this change is not certain, many studies have shown that agriculture could be affected in many parts of the world if global climate changes as anticipated (IPCC, 1990b; Rosenzweig and Parry, 1994; Rosenzweig et al., 1995).

Characterization of Agriculture and Forestry Systems in the Southeastern United States

The Coastal Plains region of the Southeastern United States has a very productive agricultural sector that produces many high value crops such as citrus (oranges and grapefruit), vegetables (tomatoes, green peppers, celery), strawberries, sugarcane, fruits & nuts, rice; and also several field crops (peanuts, cotton, maize, tobacco and soybean). This diversity in production is accompanied by equally diverse cropping and farming systems, including animal systems, aquaculture and forestry; diseases, insects, weeds, and pest-complexes. The heterogeneous nature of topography, soils, and climate (both regional and dynamic, e.g. ENSO as well as longer time scales) are unique in the US. Additionally, the relationship between managed agroecosystems and wetlands in coastal regions is not encountered elsewhere. Rainfed field crops are vulnerable primarily to drought stress, particularly on sandy soils. Fresh vegetables, sugarcane, citrus and some field crops are irrigated. However, since irrigation is not as prevalent in the SE as in other regions, stresses induced by climate variability/change are amplified. Southern Florida produces about 50% of the nation's fresh winter vegetables. Although irrigation reduces sensitivity to rainfall fluctuations, these vegetable crops are particularly vulnerable to low temperature stress, as the unanticipated January 1997 freeze painfully demonstrated. Likewise, the citrus industry has been set back by a series of severe frosts in the late 1980s.

While supplemental irrigation offers farmers options for reducing risk, irrigation raises broader concerns from the perspective of natural resource managers. The source of groundwater for irrigation in the coastal plains is rainfall in the previous one to three years. Due to the interaction between groundwater and surface waters, over drafting can have harmful effects on wetlands, lakes and streams, as well as aquifers. Aquifer recharge and water availability are likely to be least when crops need irrigation most. ENSO influences both the demand for irrigation water and its supply.

Impacts and Vulnerability

Climate variability in the SE USA has been associated with El-Niño Southern Oscillation (ENSO) activity (Ropelewski and Halpert, 1986; Kiladis and Diaz, 1989; Sittel, 1994). El Niño years tend to be cool and La Nina years tend to be warm between October and April. El Niño years tend to be wet and La Nina years dry during these months. Recent studies have confirmed vulnerabilities of some crops in the SE to climate variability. Hansen et al. (1997) analyzed historical records for six crops in four states in the SE USA (Alabama, Georgia, Florida, and South Carolina) to characterize annual variability in agriculture and to determine how much of the variability is associated with ENSO activity. They found that corn yields were high in La Nina years and low in years that followed these years. The magnitude of ENSO influence on corn yield variability was more than $200 million, or 26% of the annual average value of corn produced by these four states. The effects of ENSO activity on the values of annual soybean, peanut, and tobacco production were also significant, but not as large as for corn. Similar findings have been shown for crops in other parts of the world (Cane et al., 1994; Handler, 1984; Carlson et al., 1996). The demonstrated influence of ENSO on agricultural production and the emerging capacity to forecast ENSO events with lead times exceeding several seasons (Chen, et al. 1995) suggest an unprecedented opportunity to tailor agricultural decisions to anticipated weather conditions, either to mitigate the impacts of adverse conditions or to take advantage of favorable conditions. The value of an improved ENSO forecast to producers and consumers for four field crops in the SE is estimated to exceed $100 million per year (Adams, et al. 1995).

Few studies on climate change effects on agriculture and forestry in the SE USA have been conducted. Curry et al. (1990a) studied two crops (corn and soybean) grown under current and two General Circulation Model (GCM) scenarios. Their results suggested that yields of soybean would decline by 11% and 52% in the two climate change scenarios under rainfed production whereas corn yields would decline by 8% and 73% for the two scenarios, respectively. In addition, Curry et al. (1990b) estimated relatively large increases in evapotranspiration and irrigation water requirements for soybean under the two climate change scenarios. In a national study, Adams et al. (1989) suggested that shifts of field crops from the SE to other parts of the USA could occur under climate change scenarios.

Potential for Changes in Policy, Management Decisions (Adaptation)

What can be done to reduce the unwanted impacts of climate variability on agriculture and forestry and take advantage of positive impacts? Effective application of climate forecasts to agriculture depends on 1) the availability of regional climate forecasts of adequate lead time and accuracy, 2) the vulnerability of agriculture to weather variability, 3) the existence and awareness of options for using knowledge of future weather to improve decisions and policies, and 4) the ability and willingness of decision and policy makers to modify their decisions based on available information (Lamb, 1981; Sonka et al., 1986; Mjelde, 1993). These decision makers include farmers who choose crops, management practices, areas to plant, and resources to use; advisors in public (e.g. agricultural extension agents/offices) and private institutions who make recommendations and supply information to farmers; those who supply seed, manage irrigation resources, and provide other resources for production; and public policy makers who develop and provide information or influence decisions by policies, such as insurance, credit, and price supports. Additional research is needed to assess the likely impacts of annual climate variability and possible changes in climate on agriculture and forestry in the SE USA, and to facilitate improved decision making to reduce unwanted impacts and reduce risks. Research should be aimed at providing the necessary information, tools, and analyses to these agricultural decision makers, tailored to specific conditions in the SE region. Based on existing relationships of agricultural community to information providers, a combination of public/private approaches appears to have many advantages, but requires significant forethought regarding the role of climate forecasting centers, likely forecast products, uncertainties/skills associated with these forecast products, and delivery mechanisms/implementation plans to maximize information utilization.

Identified Stresses/Concerns:

Nutrients (fertilizers): Management of the supply, application and deposition of nutrients, including both commercially produced and naturally occurring, e.g. poultry, swine, dairy, can be impacted by climate variations. The choice of fertilizer is highly dependent on soil type, desired yields, etc. Prescriptions for application are commonly available, but do not consider climate issues. Deposition of naturally occurring materials are related to water resource and soil quality issues.

Water quality and quantity: Multiple scales (farm, county, state, region) as well as tactical vs. strategic concerns of multiple user interests make this issue very complex. For example, irrigation scheduling is typically affected by precipitation availability (in an immediate sense for crop development and on longer time scales regarding water availability/supply) but relates equally to resource management. Runoff issues directly relate to water quality, erosion and sedimentation of streams and water courses.

Soil structure and quality: The unique characteristics of soil structure and quality in the SE plays a relatively large role affecting and being affected by climate variability/change in its role for sustaining productivity. Soil quality in the SE is declining. This is partly attributable to streamflow and runoff issues and may also be impacted by climate variability.

Market Competition: Timely updates and predictions of productivity, time-to-market, and other evolving characteristics of competing markets (local, regional, international) can maximize profit. In some markets, these are directly impacted by climate issues. Thus knowledge of climate-related impacts worldwide are valuable.

Policy/Subsidies: This stress includes not only economic policies (e.g. assistance programs), but also environmental (e.g. regulatory use of pesticides). These affect farm practices and decision making flexibility. Risk factors are associated with fundamental changes of state and federal programs. To what extent should climate issues be incorporated into policy design and implementation?

Depopulation: The long term viability of rural farms is dependent upon sustained farming communities. How do rural and/or small farming operations compete with larger operations which have more resources to incorporate new technology such as climate-related management practices?

Increasing Urban Population Growth: Closely linked to depopulation concerns are the stresses associated with heightening competition for resources in urban/rural fringe zones.

Sustainable Productivity: Maintaining yields and/or profits from agriculture and forestry activities is the ultimate stress/concern on the farming community in the SE USA.

Climatic Variables

Precipitation, temperatures, solar irradiance, wind, and humidity are all key variables with demonstrated or likely impacts on identified stresses. The diverse nature of these stresses for the agricultural sector in the southeastern United States necessitates a quantification of climate variability/changes over a wide spectrum of temporal and spatial scales. For example, fairly precise predictions of extreme events as well as shifts of agriculturally relevant characteristics are required because of the critical nature of their intersection/impact on farming system development (plant growth, harvest, scheduling, etc.). Climate variables currently available are often insufficient (spatially and temporally) to adequately address probable climate change/variability induced impacts.

RECOMMENDATIONS

Based on discussions during the SE Regional Workshop, we identified areas in which multi-disciplinary activities should be encouraged in order to first probe and then field-test first order impacts of incorporating climate variability/change information into a number of agriculture-related systems. Additionally, given the limited participation of the user-community in developing these recommendations, we encourage additional review of pertinent planning documents in order to maximize involvement of the agricultural communities in future activities.

I. Research

Develop, validate, and evaluate new technology *capabilities* (e.g. climate forecasting, remote sensing, precision farming).

A multi-disciplinary approach involving scientists, producers, private sector, government, non-government entities and users should focus on first identifying the agriculturally-relevant capabilities of new technology, and then developing, validating (through modelling and experimentation), and evaluating experimental products suitable for utilization in agriculture systems.

Develop, validate, and evaluate agriculture models (cropping systems, grazing, disease, watershed, production) with regards to climate forcings.

It is not clear that current models correctly respond to climate forcings. Many agriculture system models do not include climate forcings as a driver. Expanding current modeling development activities to cover a much wider range of farming systems will address a larger number of the identified stresses on the agricultural system and provide a testbed for exploring the experimental products described previously. Further development of multi-system models would be particularly welcome for investigating the relations between complex systems such as water, soils, nutrients, and production.

Relevant agricultural mitigation options need to be explored, especially those related to change of climate variability (greenhouse gases, etc.).

Two types of mitigation options are recognized as critical components to adaptation of new information: 1) those identified as reducing undesirable impacts of climate variability; and 2) those identified as related to climate change (e.g. reducing greenhouse gases).

II. Application:

Because the incorporation of new climate-related technology capabilities into agriculture systems is relatively new and yet unproven, pilot projects should be identified to explore transfer/communication and adaptation issues.

This collective effort should involve public and private constituents as well as the end users to foster multiple feedbacks and to optimize the adaptation process. The county extension delivery system and individuals associated with it are valuable resources and can play an important role. Communications should include discussion of risks, uncertainty, and trade-offs between skill and confidence.

Agri-climate programs being developed in South America and already implemented in Australia can serve as models for implementation, however fundamental differences in policy, infrastructure, and farming practices may limit transfer of knowledge base and subsequent application to the southeastern United States.

III . Post-Meeting Review, and Implementation Activities

Additional stakeholder participation in subsequent review and implementation planning of regional plans is encouraged. After the SE Regional workshop, continued/additional communications are recommended in order to prepare future activities. More formal organizational structures may be required to foster continued interest and generation of results by scientists, producers, private sector, government, non-government entities and users.

IV. Funding

There is an expressed need for funding mechanisms to support agri-climate research, particularly those multi-disciplinary efforts aimed at translating/transferring identified basic research results to users and user-specified applications.

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b. CLIMATE VARIABILITY AND ITS IMPACT ON SOUTHEASTERN COASTAL RESOURCES

Margaret Davidson, Session Leader
Virginia Burkett, Reporter

The group which focused on this topic area was comprised of a fisheries scientist, a wetlands scientist, a government data assimilation scientist and a coastal policy analyst. Our small group met and developed a matrix for identifying the interactions between climate variables and the interwoven coastal resource ecosystems of the southeastern US. After we worked through the general state of awareness that was possessed by our group, we then began to discuss the relationship between existing stressors and the degree to which those impacts were be further exacerbated by changes in climatic variables.

After developing the matrix and the reference list of existing stressors, we then systematically discussed the current status and existing gaps in our understanding of the interactions between the climatic variables and the various representative ecosystems. This information is encapsulated under the section entitled ‘Data Needs’. It is readily apparent from our discussions that much more needs to be done to further our understanding of the relationships and effects resulting from changes in temperature (ambient air and water column), carbon dioxide, and UV-B. There are very complicated feedback loops within and across these ecosystems which would further complicate the interactions and effects: our ability to understand these feedback loops and tease out the resultant impacts is very limited.

We then identified a number of ‘activities’ that could be readily undertaken which would mitigate known or presumed impacts. A number of these refer to efforts already underway that would ‘buy time’ until we do have better understanding of the range of change and effects. For instance, it would be most appropriate to repeat the western experience of 'flush and flow' release of rivers to help restore marginalized riverine ecosystems: this might strength the resiliency of various organisms. In addition to specific actions such as expanding river corridor protection, promoting bypass mechanisms during the course of FERC relicensing of the many dams found throughout the region, and working harder to expand setbacks and conservation easements. We also recognize that as a society and community, we need to work harder on communicating the importance and seriousness of these issues to a broad audience throughout the region. Further, we need to recognize that the southeastern US is closely interlinked with its Mexican and Caribbean neighbor.

Our final task effort was to identify approaches and tasks that should be undertaken by the scientific and decision making communities to enhance our ability to both understand and respond to the range of associated impacts. These recommendations include:

1. Our approach which currently relies on biogeographical provinces needs to be expanded to includes climatic relationships. Further, we should link various 'controlled use' sites around the region to develop a baseline reference system for studying change. These would include the National Wildlife Refuges, the National Estuarine Research Sites, the LTERs and LMERs supported by NSF.

2. The community needs to develop clearer statements (in plain English) about various projects, probable impacts and the relative level of certainty (and just what that means).

3. We need to do a better job of integrating climate variables to improve interannual forecasting because that is the level of frequency that is most important to sensitive ecosystems.

4. We need to integrate socioeconomic variables with climate variables so that the 'real' impacts---especially long range economics--can be clearer to decision makers. We also need to build upon the work by Costanza et al in quantifying the economic value of our natural ecosystems.

5. We need better compilations of life history data for these ecosystems so that managers can better understand range of impacts and assess mitigative actions.

6. We also need to improve our understanding of carrying capacities for these ecosystems, particularly since they are already substantially stressed by anthropogenic influences

7. We must recognize (and communicate) that coastal ecosystems-and particularly estuaries- do not have unlimited capacity to respond to the changes that are occurring: changes in climate reduce resilience, increase stress, and have profound negative impact on productivity and diversity.

8. We need to figure out how to bridge interagency turf particularly vis-à-vis sharing data. This involves states, federal agencies, and universities.

9. Finally, we need to do a much better job of communicating and educating the broad citizenry about the importance of these systems, the nature and range of probable changes, and how it will impact our lives and our economy.

EXISTING STRESSORS

Hydroalterations:

Dams, channelization, dredge & fill, water withdrawals/additions
sheet flow disruption, sediment changes

Infrastructure:

Sea walls, jetties, dams, barriers to biological organisms

Pollution:

NPS, atmospheric, sos, industrial & murk discharges, spills, elutro pug forms
Cumulative impacts/depleting uses/overharvests/exotic/invasive species
ATV/PWS/ships/coral
Fragmentation of habitats

DATA INFORMATION NEEDS

1. Sea Level Rise: ESTIMATES, LATE/TIME PERIODS:
   Tools to distinguish global from regional/local
   Relation to circulation/estuaries
   Vulnerability assessments:
   - regional & local scale
   - plant communities at risk
   - fine scale modeling/GIS --> planning

   Better monitoring: tide gauges, GPS, RS
   Storm surge: update slosh slam etc.
   Finer Coastal topography

2. Precipitation: Historical trends, finer scale modeling
   relationships --> sinkholes, perched water tables
   more/better proxy/analogs
   specify relation - BE/rainfall/flows & aquatic species

3. Extreme Events:
   Frequency - }
   intensity - } timing/delivery
   duration - } 200^{+} yr record: analog/anecdotal
   ? = Os of departure overtime
   - information on sub-regional scale or place-based
   - how do natural perturbations occur

- overall perturbation environment (floods, droughts, storms)
- for each biogeographic area, has there been a departure from the norm
  Products: climate/biography class. Framework - GIS layer

4. T^o -temp. sensitivity of tourists
   -location of thermal affluents
   Species distribution; sea temperature charges:
   examples: Formosan termites, plants
   -more rapid turnover rate
   -interaction w/nutrient cycling ?/decomposition rates
   -growing season & productivity
   -effects on dissolved CO_2 + O_2
   -Increase in disease vectors (Vibrio example)
   Products: ? GOM thermal maps
   - updates, synthesis documents

5. CO_2: -need to understand pathways
   -response of living organisms to enriched carbon
   -pH + CO_2 interactions affects on freshwater + blood
   -magnitude unknowns

6. UV_B: -does this impact plant reflectance/i.e., insect recognition
   -physiological (dose) response of plants & animals to UV_B
   -diminished productivity in top meter of water

MITIGATION

- river corridor:

protection/preservation

- "flush and Flows"
- FERC relicensing process (promote) and bypassed
- revised, actuarially-based NFIP (national flood insurance programs)
- setbacks: easements: developing rational arterial
  -for ID priorities, incorporate climate variables, (Costanza's work/recognize value of coastal ecosystems)
- reinvigorate stewardship authorities & basis for decision-making - stewardship ethics

* - international connections - communication/education

OVERALL NEEDS

1) Geophysical province references sites
   NWR, NEERS, LTERs, LMERs add in climate
   (link these as reference sites)

2) Broad use of indicator species as affected by climate variables

3) Clear statements about projections & level of certainty

4) Integrate climate variables to improve interannual forecasting

5) Integrate socioeconomic variables w/climate to increase appeal to decision values

6) Better compilations of life history data for managers

7) Carrying capacities.

Must recognize that estuaries do not have <u>unlimited</u> capacity to respond to change that are occurring

>s's = resistance, stress, production + diversity

8) Bridge interagency data/turf - Universities, States, Federal agencies

9) Communicate + educate

c. Southeastern Science Education Sector

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Summary

Since education cuts across each of the breakout topics, there are many opportunities for the educational community to contribute to the climate research agenda: to use scientific results, to enhance educational programs, and to educate future generations of teachers on how to implement earth system science programs.

From the educational perspective, the most important recommendation is to promote the adoption and expansion of existing authentic learning programs, i.e., curriculum programs that involve students in the solution of real problems. Networks for the collection and reporting of data are currently being established by the GLOBE Program (Global Learning and Observations to Benefit the Environment), an international environmental education and research partnership established by Vice President Gore. More than fifty-five countries and over 4,000 schools worldwide have trained teachers to lead their students in taking environmental data on or near their school campuses. This data is then entered into a data archive by the students via the World Wide Web. Students are allowed to **BE**

SCIENTISTS as they enter information about their GLOBE site, retrieve and analyze their own data and the data of all other contributing students, and see visualizations and graphs as a means of understanding trends.

The upcoming Global Water and Energy Cycle (GEWEX) Continental-scale International Project (GCIP) in the Southeast was suggested as a candidate program for establishing a partnership between the scientific and educational communities to demonstrate this approach. The intent is that an increase in the number of participating schools and informal science programs will, in turn, enable local and regional modeling opportunities. The goal is to engage learners in not only the collection of data but the manipulation and interpretation of the data as well. This Southeastern initiative will also make possible the study of relationships between climate variability and select biological, hydrological, and geological indicators. Such a program represents an exciting earth system science education opportunity and one that is consistent with the National Science Education Standards.

Introduction

Education is a form of communication. This was the general message from each of the science sectors represented at the Climate Variability Conference. During the summary reports there were wide ranging discussions about both the audiences who would benefit from receiving climate variability information and the possible mechanisms for getting such information out. Due to the complexity of the problem of communicating scientific information to so many constituencies it became apparent that a ‘quick fix’ approach would not be effective. Rather, a solution to the problem would require, among other things:

- a long term systematic educational strategy across K-16 grades;
- the involvement of both formal and informal sectors of education;
- scientists and scientific agencies reporting data and results in forms useful to local, regional, and state decision makers in the various conference science sectors;
- the involvement of non-scientists and young scientists to expand and carry-out land-based measurements;
- new preservice and inservice teacher education programs;
- new undergraduate science courses of study and degree programs;
- use of the Internet to disseminate and collect data, models, and reports; and finally,
- educational research to evaluate and understand effective models of curriculum, instruction, and assessment as well as outreach programs that

improve the public's understanding of the impact climate variability has on environmental, demographic, and economic constituencies.

During the workshop, members of the education breakout sessions presented and discussed a variety of concerns and strategies. We have organized these into three broad categories presented in the form of questions: *How can education contribute to the research agenda? How can educators use scientific results to enhance education? How do we educate the public and decision-makers?* In the three sections that follow, critical issues are presented followed by brief statements that elaborate on key ideas.

Section 1 - How can education contribute to the research agenda?

Promote adoption of education programs that involve learners in data collection, data manipulation, data interpretation.

There exist several curriculum programs designed to engage students in the doing of science. Examples include the GLOBE Program; Earth System Science Education (ESSE), an undergraduate program sponsored by NASA; and problem-based curriculum units such as *Mission to Mars* developed at Vanderbilt University. Teachers in the Southeast should be made aware of these programs and be provided with support programs for first learning and then using the curriculum.

Explore the possibility of enhancing the spatial and temporal density of land-based measurements.

The upcoming Global Water and Energy Cycle (GEWEX) Continental-scale International Project (GCIP) in the Southeast was suggested as a candidate program for establishing a partnership between the scientific and educational communities to demonstrate this approach. Students and teachers properly trained can contribute to the data base scientists use to model climate variability in the Southeast. Successfully recruiting teams from schools, museums, parks, clubs, etc. would simply provide more and more frequent land-based measurements.

Recruitment and training of teams of individuals to coordinate, implement and report measurement activities.

Creation of more GLOBE franchises (organizations who recruit, train and mentor GLOBE schools) and consortia of these franchises to introduce educators to research protocols,

A concerted recruitment effort for schools in communities across the Southeaster states must take place in a short period of time. The land-based measurements by formal and informal education sectors must be useful to scientists studying climate variability in the region. The GLOBE program has developed an effective model for training teachers to assist their students in conducting several environmental measurements across the United States and internationally. However, GLOBE is in use in a relatively small number of schools across the Southeast states. GLOBE training efforts should be expanded across the region.

Promote the involvement of both informal (e.g., parks, zoos, nature centers, science centers, after school programs) and formal science education sectors of society.

Establish Partnerships between cohorts of schools/informal agencies and scientific constituencies.

There are many fine science education programs in parks, museums, zoos, nature centers, and science centers in the Southeast. Schools should be encouraged to collaborate with informal science education programs and science agencies in the collection of climate variability data. Such a partnership would promote year round data collection.

Evaluate college programs of study (undergraduate & graduate) for educating the present and next generations of educators, engineers, policy makers and scientists.

Training of preservice and inservice teachers to use environmental data gathering programs;

Traditional science programs of study do not engage students in a consideration of environmental, demographic, and economic applications of climate variability scientific knowledge and information. Local, regional and state decisions must then rely on federal agencies for data and recommendations. However, the resolution of federal models are not fine-grained enough to assist local and regional decisions makers. Extension services provided through state land grant universities will need to be utilized and expanded.

Identification of measurements and analyses (Micro Models) that can be carried out by students (K-16).

Merely contributing to the collection of data will not, in the long term, motivate or stimulate students to investigate the complex relationships of environmental, demographic, and economic applications of climate variability scientific knowledge and information. Local and regional problems students both can generate, extend and investigate are needed to provide the appropriate cognitive and social context for doing science.

Establish Leadership Team from research areas and stakeholders across the Southeast.

During the next two years an intensive scientific study of the southeast United States will seek to improve the resolution of information about climate variability and its impact on water resource management issues. Science educators and policy makers in the Southeast have an opportunity to engage in education research and development activities as a part of the scientific study. Efforts will be made to coordinate GLOBE and other similar environmental education and research programs across the Southeastern region.

Section 2 - How can educators use scientific results to enhance education?

Identification of project-based science themes.

Access to data sets for student modeling and analysis.

Authentic scientific questions can be investigated by students. Access to data and models via the Internet make it possible for students to analyze data collected locally, construct and test models and then compare these results with regional and global models.

Address the National Science Education Standards with an emphasis on doing science as inquiry and on social perspectives of science.

The reform and restructuring of schools is a national problem. A curriculum focus on climate variability and subsequent effects on environmental, demographic, and economic factors fits well with the content standards of the *National Science Education Standards*. Changes in the design of learning environments are needed though to make science learning inquiry based. Research in cognitive and social psychology over the past three decades has contributed to our understanding of ways to promote learning with understanding. (See Appendix A for a list of 7 principles for the design of learning environments).

Access to data for risk/benefit analysis of extreme climate variables.

The trend in science toward the increased use of statistical and probabilistic models presents a challenge for a decision-maker unfamiliar with the reasoning strategies used with such models. Access to such data would allow K-16 programs of study to develop age appropriate activities for understanding and then acting on extreme climate conditions. Similarly, programs could be made available to the private sectors who use climate variability data.

Cooperative agreements with scientists to promote and sustain curriculum innovations.

As our understanding of climate variability and the impacts it has on environmental, demographic, and economic conditions grows, so must our programs of education reflect such changes. Efforts should be made to establish cooperative agreements at local levels in both inter and intra institutional contexts.

Access to summary results, visualizations, and computer modeling and analysis skills that are comprehensible and useful to K-12 students and teachers;

Access to clearly identified science objectives, problems, deliverables.

Constituencies develop age appropriate techniques, classification and identification schemes, and indicators (i.e., GLOBE Program 'cloud charts') for monitoring trends of critical variables.

To insure maximum benefit, the scientific community must be willing to share information that others can use. At times this will require the scientists themselves to prepare data sets and models for general dissemination. At other times, scientists would work in cooperation with individuals charged with formatting scientific information for dissemination of various public sectors. Especially important is the need for the science sectors to identify the critical variables and techniques used to monitor climate variability. Only, then, can formal and informal science programs contribute to expanding the spatial and temporal range of land-based measurements for use with local and regional decision making.

Section 3 -How do we educate the public and decision makers?

Educate the future generations of teachers to implement earth systems science programs.

Make alterations to undergraduate preparation of scientists and science educators.

The advancement of technology provides new tools for studying the Earth. The explosive growth of the Internet has provided a platform for the rapid exchange of information. By using the Internet, GLOBE students can communicate with any other school participating in the GLOBE Program. Already many research projects are being done jointly by students from other countries using this tool. A challenge for science educators and policy stakeholders is providing the instructional frameworks that provide age-appropriate experiences for understanding data collected as part of the Mission to Planet Earth and regional research programs.

Teachers dedicated to integrated learning are already seeing the connections. Children are using their reading skills as they do research and as they engage in communications. Written and oral communication skills are perfected, as students express their findings, hypotheses, and conclusions, as they make detailed observations of their study site, and as they keep scientific journals. Geography skills are used as students locate schools by latitude and longitude, use the Global Positioning System (GPS) to accurately locate their own school, or learn about the culture of a school in a different environment. Every aspect of science, including physics, chemistry, geology, biology, and even health will be used as students explore the dynamics of our planet's biosphere. The arts can be used as students search for the most meaningful, concise, and creative way to communicate their ideas. In short, students can learn content to meet the National Science Standards in an engaging, inquiry-based framework.

The study of the Earth as a system needs to be enhanced in undergraduate science programs and teacher education programs. The scientific investigations of the interactions between the lithosphere, atmosphere, hydrosphere and biosphere require programs of study that adopt an interdisciplinary perspective. The Earth System Science Education (ESSE) program strives to provide the interdisciplinary framework for the undergraduate education. More effort needs to be made in bridging between the schools of science and the schools of education in the Southeast as well as the rest of the nation.

Establish cooperative education programs with scientists and stakeholders.

Efforts should be made to establish cooperative agreements at local levels in both inter and intra institutional contexts. By leveraging federal, state and local research opportunities, we can better utilize the resources at hand. The GEWEX and the GCIP research programs could provide a platform for partnership between the scientific and education communities in the Southeast during the next two years.

Establish scientific journal created for children and run by children.

Promote and publish involvement of students in collaborative research projects.

Publication of student measured environmental data would enhance the authentic learning process. These journals could be used as a means for communicating data and analyses from GLOBE schools across the Southeast. The GLOBE Program Office is currently planning to provide the infrastructure for an electronic scientific journal to be written and edited by and for GLOBE students from around the world. Efforts should begin in the Southeast to utilize this forum as an authentic learning tool.

Build partnerships with institutions that serve the public's recreational and informal education interests; e.g., nature centers, extension services, park visitor centers, libraries, cooperative extension agencies, etc.

National Parks in the Southeast (numbering 62 in the Southeastern United States) can serve as collaborative sites between informal and formal educational programs. Individual parks located in different physiographic provinces can become labs for monitoring relationship between climate variability, scientific sectors, and the various environmental, demographic, and economic constituencies in the Southeast. Individual classrooms, programs or cohorts of schools can become research partners with Park staff and visitors. The goal would be to monitor and model the patterns of select physical, biological, hydrological, and geological indicators of importance.

Park personnel could highlight site specific problems that schools could investigate. Schools, in turn, would propose data gathering activities after an analysis of models of the Park. Park staff and visitor science educational programs would implement both newly proposed and ongoing data gathering activities. In this way, any school in any region of the Southeast could participate in research of any Park. Research problems, methods, and reports could be monitored by a grade/age appropriate peer review panels. Publications announcing the program and providing reports of student research would be made available to Park visitors. Park brochures could advertise research opportunities/programs at their location.

A demonstration project such as this could show how climate change could impact local and regional resources. It could also serving as an example of how can education contribute to the research agenda. Formal and informal educators could also use scientific results to enhance science education and demonstrate the relevance of climate change at a local level.

Seven Principles
to
Guide the Design of Learning Environments

Robert Glaser (1994), keynote address delivered at the 23rd International Congress of Applied Psychology, Madrid

1. *Structured Knowledge* - "Instruction should foster increasingly articulated conceptual structures that enable inference and reasoning in various domains of knowledge and skill. Education that teaches isolated memorization of facts and definitions of concepts will not accomplish this purpose"

2. *Use of Prior Knowledge and Cognitive Ability* - "[R]elevant prior knowledge and intuition of the learner is . . .. an important source of cognitive ability that can support and scaffold new learning . . . . . the assessment and use of cognitive abilities that arise from specific knowledge can facilitate new learning in a particular domain" (p 18).

3. *Metacognition: Generative Cognitive Skill* - "[T]he use of generative self-regulatory cognitive strategies that enable individuals to reflect on, construct meaning from, and control their own activities . . . . is a significant dimension of evolving cognitive skill in learning from childhood onward. . . . These cognitive skills are critical to develop in instructional situations because they enhance the acquisition of knowledge by overseeing its use and by facilitating the transfer of knowledge to new situations . . . [T]hese skills provide learners with a sense of agency." (p 18).

4. *Active and Procedural Use of Knowledge in Meaningful Contexts* - "Learning activities must emphasize the acquisition of knowledge, <u>but</u> this information must be connected with the conditions of its use and procedures for it applicability. . . . School learning activities must be contextualized and situated so that the goals of the enterprise are apparent to the participants" (p 19, emphasis in original).

5. *Social Participation and Social Cognition* - "The social display and social modeling of cognitive competence through group participation is a pervasive mechanism for the internalization and acquisition of knowledge and skill in individuals. Learning environments that involve dialogue with teachers and between peers provide opportunities for learners to share, critique, think with, and add to a common knowledge base" (p 19).

6. *Holistic Situations for Learning* - "[L]earners understand the goals and meanings of an activity as they attain specific competencies. . . . [C]ompetence is best developed through learning that takes place in the course of supported cognitive apprenticeship abilities within larger task contexts" (p 19 -20).

7. *Making Think Overt* - "[A] significant mechanism in environments for learning is to design situations in which the thinking of the learner is made apparent and overt to the teacher and to students. In this way, student thinking and reasoning can be examined, questioned, and shaped as an active object of constructive learning" (p 20).

d. EXTREME EVENTS

Roger A. Pielke, Jr., Session Leader
Rick Piltz, Rapporteur

Extreme events are a theme which cuts across each of the breakout groups.

FINDINGS

* Extreme events have a considerable impact on stakeholders in the southeast region. Examples discussed include energy, emergency management, and water resources. Data on impacts is available for some phenomenon (e.g., floods), but not others (e.g., droughts).

* There are different types of extremes:

    - statistical extremes associated with probabilities of exceeding some arbitrary threshold. These extremes can be associated with events of high frequency/low magnitude. For instance, for some construction companies rainfall events of greater than 0.10 inch disrupt business operations.

    - impact extremes associated with a large net impact on society or environment. These can be typical events which are not extreme in a statistical sense (i.e., medium frequency/high magnitude) but have a large impact. Hurricanes, floods, droughts, ice storms, cold spells, and heat waves, are examples.

    - extreme extremes associated with catastrophic impacts on society or environment. These events are also extreme in a statistical sense (i.e., low frequency, high magnitude). An example would be a Category 5 hurricane striking New Orleans.

* The southeast is becoming increasingly vulnerable to extreme events. This means that impacts would likely increase without changes in climate that increase the frequency or magnitude of extremes. (The possibility was raised that in some cases impacts would increase *even if* extreme events became less frequent or severe, e.g., as has been documented in the case of hurricanes.) Climate surprises or changes in variability which increase the frequency or magnitude of extremes would impact a region increasingly sensitive to their impacts.

* Climate extremes are one of many stresses in the region. Population growth, land use, urbanization, development, and technological sophistication are among the factors that serve to increase societal and environmental vulnerability to extreme events. While a few sectors/stakeholders have become increasing resilient to climate, many have not, and have actually become more vulnerable.

* Because climate extremes are one factor in a complex inter-related system of stress, the way in which we research extremes must take that complexity into account in order to understand the relation between climate extremes and stakeholders.

* Use of climate information varies contextually; i.e., different stakeholders have different needs, levels of sophistication, and sensitivities with respect to extreme events. Availability of information on extreme events does not necessarily mean that it will be used.

* Many stakeholders do not fully use existing climate information related to extreme events. Using climate information has become increasingly important to some stakeholders as the business environment has become more competitive and decision makers look to better understand the exact nature of risk in their decisions. The example of Scottsdale, AZ was cited as an example of an extremely sophisticated user of climate information.

* In some cases, stakeholders have sufficient climate information related to extreme events. In such cases obstacles to reduction of vulnerability lie in other areas, e.g., such is largely the case in improving floodplain management. Often it is the occurrence of an extreme event which triggers stakeholders to improve their response.

* In general, with respect to extreme events seasonal and inter-annual climate information/forecasts are of more use and value to stakeholders than is information on decadal/century timescales. In other words, stakeholders respond to climate variability, not climate change. There are exceptions, such as floodplain development and other large-scale capital development which require consideration of climate variability over the longer term.

* Reduction of vulnerability to extreme events will also contribute to preparation for the impacts of climate change (whatever the scenario). In other words, "no regrets" adaptation efforts make sense, given documented sensitivities to impacts associated with extreme events.

- The issue of extreme events, preparing for and responding to them, will remain regardless of how the climate changes long-term.

RECOMMENDATIONS

* Maintain and extend our ability to collect, analyze, and disseminate data related to

climate over the long term. In the case of extremes, such data has a demonstrable relationship to decision making.

* Given that societal and environmental problems associated with climate extremes are complex, data must also be collected with respect to the non-climate factors which play a part in the cause of the problems or which serve as a measure of impacts (i.e., social and environmental indicators). Research must focus on the interactions between climate extremes-society-environment.

* Focus on utilizing the historical climate record better than we have in the past to understand the range of observed climate extremes and the spatial and climatic patterns associated with their occurrence. The O'Brien tornado study is an example of such a study.

* Continue efforts to develop climate forecast tools, including development and implementation of probabilistic tools.

* Bridge building must increase. For instance, develop processes to ascertain what climate information/tools would be of use to stakeholders. Also for climate information to be of great usefulness to stakeholders, they must understand it in the context of the extreme event-related decisions which they face. To enhance the linkage between climate science and stakeholders support existing organizations and groups such and National Climatic Data Center, Regional Climate Centers, and State Climatologists. This linkage also includes activities such as this workshop and other activities which bring together scientists and stakeholders. Other possibilities including making use of invited/targeted research proposals focused on particular issues of concern to stakeholders.

* View climate change mitigation (e.g., emissions reductions) and adaptation to extreme events as complements, not as tradeoffs. There is a commensurate need to understand the economics associated with each.

e. IMPACTS OF CLIMATE CHANGE ON PUBLIC LAND MANAGEMENT

Hubert Hinote, Session Leader
Suzette Kimball, Rapporteur

General Comments

Region forecast to be fastest growing in the country – public lands provide amenities that promote population migrations

Public land manager - not managing for economic return, managing for the long term ("for future generations") – different management ethic than private interests.

(Godschalk, Berke and Kaiser, 1997): Governments subsidizing risk associated with using sensitive areas results in exacerbation of pressure and resistance to change and variability.

System of parks and refuges leads to expectations that a natural area can be preserved in situ over time; management strategies are not coping with the concept of natural evolution of place

Southeast region as a whole has great range of microclimates and habitats and tremendous biodiversity – insular areas such as parks and refuges can be areas particularly sensitive to small changes in natural factors

Most public lands carry multiple-use mandates (e.g., visitor accessibility and habitat conservation), which makes management more difficult when natural variables (climate) are changing and the impacts of those changes are not well understood.

Current Concerns and Stresses in the Region

Demographic shifts – more people in the area and increasing rates of development – how to provide the amenities and infrastructure needs for water supply, roads, agriculture, etc., without destroying the aesthetic values that brought the people to the area.
Expansion of tourism in an area undergoing economic growth creates pressures in protected areas; even ecotourism creates stresses to fragile habitats and populations.

Even in areas not undergoing growth, there is a greater level of use of public areas –more visitors demanding greater variety of services and activities.

Current fiscal conditions results in the managers of public areas being stressed – leads to reactive (crisis) management rather than proactive long-term planning.

More people in the region requires community managers to provide more water, agricultural products, employment, etc., which impacts the ability of the natural system to absorb the effluent of all the various activities; extremes of climate and systematic changes in the hydrosystem exacerbate those pressures, increasing pollutant loads.

Introduction of non-native, invasive species threatens native populations.

Results: habitat fragmentation; island biomes; water pollution; air pollution; nutrient additions; salt water intrusion .

Role of Climate Variability to Amplify/Lessen Stresses

Rate of change more important than absolute magnitude of change ; land use pressures and habitat fragmentation preclude rapid-response migration and adaptation.

Mind of developers – land use change causes more change than climate: reduced migration corridors, use pressures preclude adaptations; public lands become more insular variability -- development can make remaining fragments of natural areas more vulnerable to change.

Water temperatures – throw reproduction and food production cycles out of sync.

Temperatures and water levels impact the interaction of noxious weeds and other organisms and native species – many invasive and opportunistic species have wider ranges of tolerance than native species.

Managing recreation areas – high and low flows and the distribution of those flows on an annual cycle are important for managing water-based recreational activities (fishing, boating, rafting, kayaking, etc.).

Public water supplies – managing reservoirs including recreational use is dependent on flow regimes.

Increasing water levels and temperatures, forces habitats upslope, but development immediately adjacent to protected areas often precludes migration, further restricting the "core habitat" protection afforded by public land designations.
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Information and Data Needs

Inadequate information about organisms/habitat in public areas (need baseline inventories).

Data and information – a lot of info available, but not accessible -- public managers are particularly interested in shorter time scales (decadal fluctuations); storm predictability; extreme events.

Need to know baseline information and dose response for multiple stressors (organisms in insular environments will feel pressures from several factors, not just climate change).

Spatial resolutions need to be refined – elevation effects (3-D projections).

Information needs: the managers don't need data, they need information that is directed to specific management issues (e.g., forest manager needs to know forest health: pests, fire,).

Predict viability of organisms or communities of organisms under a suite of stresses – non-linear responses (thresholds beyond which organisms cannot adapt or recover).

Predictions in short range – wetter/dryer; stormier/less stormy --- ENSO variations for management – small variations in temperature not critical to manager at this predictive level..

Location of public structures – predictive process information for infrastructure design (e.g., flooding, erosion, etc.).

Need to develop long-term monitoring strategies in order to make course corrections in management strategies as conditions change.

<u>Coping Strategies</u>

Range of actions –
Do nothing (natural regulation) – face loss of biodiversity and habitat over the short-term; can no longer afford to ignore impacts of adjacent land-use pressures combined with natural progressive change.

Need to --
develop firm federal policy on infrastructure in public areas (do not exacerbate or expand development pressures from outside the public area into the area or create more fragmented systems),

promote regional cooperation for maintenance of community continuity (greenways; conservation easements, etc.) to allow for adaptive change in habitat/biological communities, and

develop new ethic – recognize the dynamic nature of natural areas and promote the concept of evolution of place – define landscape as change and accept change as integral part of system (education and outreach activity).

(Markham and Malcolm, 1996): resilience to change can be increased by (1) conserving biological diversity (2) reducing fragmentation and degradation of habitat; (3) increasing functional connectivity among habitat fragments, and (4) reducing anthropogenic environmental stresses.

(Stohlgren, 1997): (1) Maintain or restore natural disturbance regimes in order to minimize impacts of climate-induced changes during extreme events.

(Malcolm and Markham, 1997): Promote the use of public lands as core habitat for species survival as climate changes (requires working with communities to develop greenways and conservation buffer zones around the protected areas).

f. URBAN AREAS AND HUMAN HEALTH

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Center for Clinical Toxicology

This session explored the potential influences and effects that climate variability and climate change or disruption could have on urban areas and human health in the southeastern United States. Because cities are the home to 80% of the population of the United States, the interrelationship between human health and the urban environment is inextricable. Thus, climate variability or change would not only impact the functioning and environmental characteristics of the city as an entity, but would also have potentially significant effects on the health of the human populations of cities. Additionally, urbanization exists along with deforestation and agriculture as the most profound example of human alteration of the Earth's surface. Changes that result from urbanization impact biophysical, hydrological, and climatic processes, which in turn, affect adjacent natural ecosystems. These influences brought on by urbanization, particularly those related to the affects on climate, can extend from the local to the regional scale, depending upon the size of the city and other factors. Urban areas, therefore, can not only be affected externally by climate variability or change, but can also influence the development of local or regional climatology. Ultimately, human health can be both directly and indirectly affected by these climatological processes, which can have very pervasive impacts on human society.

The real goal of our session was to view how climate variability and change affects cities in the southeastern U.S. as sustainable, habitable environments. The southeast is one of the fastest-growing regions in the nation. To insure that urban areas in the region will be capable of sustaining habitation by our children and their progeny in the next millennium and beyond, we must become aware of how the perceived impacts of climate variability and change as we know them today, will affect cities as livable environments. From this perspective, we viewed climate variability and change on cities, along with the impacts of urbanization on local and regional climate, as a series of interactions and effects as illustrated in Figure 1.

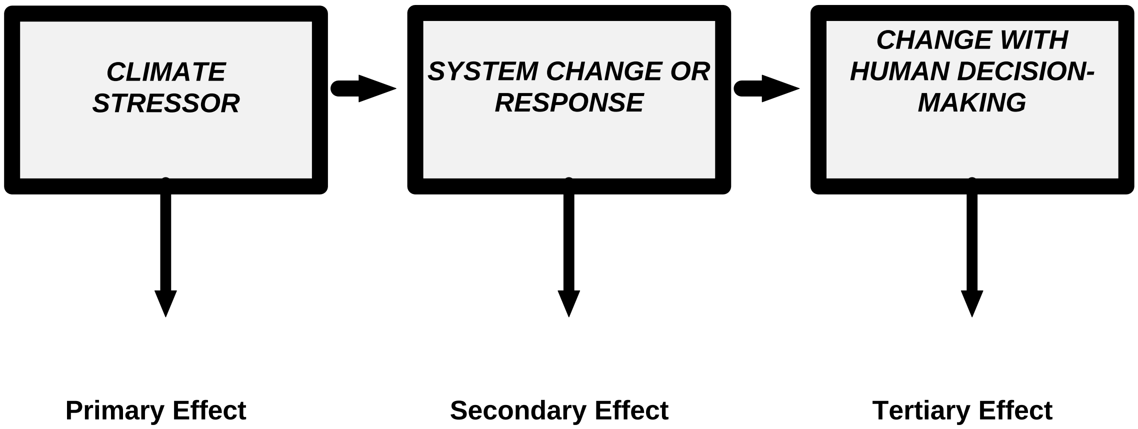

Figure 1. Relationship of primary, secondary and tertiary effects of climate variability or change as a function of processes-responses on urban areas and human health.

From Figure 1, primary effects of climate variability or change can be measured as major stressors on urban areas and human health; for example, climate change would potentially impact air quality that could be measured as an increase in ozone concentrations over cities. Climate variability or change on urban areas and human health would also have secondary impacts that would not be felt immediately, but would precipitate a change in the urbanization process or affect human health; e.g., a secondary effect of climate on air quality would be loss of tourism or population from an area because of "dirty" air or the cost of coming into compliance with air quality attainment standards. Tertiary effects are associated with changes in the decision-making process as an adjustment or adaptation by humans to climate variability or change; for example, degradation in air quality brought on by variability or changes in climate would force actions to mitigate or reduce further air quality impacts by developing alternative fuels and transportation or industry restrictions, along with bearing the substantial costs associated with implementing these measures.

The strategy outlined in Figure 1 was used to define 10 key categories that could be impacted or affected by climate variability or change, along with their attendant effects on urban areas and human health: 1) Air Quality; 2) Severe Storms; 3) Floods/Droughts; 4) Human Health; 5) Stormwater; 6) Water Management; 7) Energy Management; 8) Food Supply; 9) Urbanization; and 10) Political Risk. The data needs for observing, measuring, and modeling the impacts of climate variability or change on each of the 10 categories were also identified; e.g, to track air quality, air quality monitoring, and temperature, humidity and wind data are required. In addition to defining the primary, secondary, and tertiary effects on each of the 10 categories, mitigation strategies or programs that could be used to alleviate the impacts of climate change or variability on urban areas and human health were also identified. For example, tree planting programs or emission controls could be some of the ways that air quality degradation over cities could be mitigated or improved. The end product of the breakout session was the development of a matrix that presents the 10 categories, along with the primary, secondary, and tertiary effects, data needs, and mitigation strategies given by category. This matrix is presented in Appendix C..

Eight of the 10 categories presented in the matrix are listed in order of seriousness of impact on urban areas or human health as a response to climate variability or change. The first four categories, Air Quality, Severe Storms, Floods/Droughts, and Human Health in actuality were ranked equally in importance as far as being affected by climatic variability or change. Water Management, Energy Management, and Food Supply were perceived as being less egregiously affected by climate variability or change than the first four categories. The last two categories, Urbanization and Political Risk, exist to some extent as "outliers" from the preceding eight categories, but still warrant attention in respect to analyses of climate variability and change effects. Urbanization relates primarily to the effects and dynamics associated with the city-building process and the growth of cities on the local an regional climate, such as that exhibited by the Urban Heat Island phenomenon where air temperatures over large urban areas are elevated in contrast to their rural surroundings. Political Risk pertains to the possible loss of the public's confidence in political leaders that could result from either not responding, or not responding quickly enough, to the effects of climate variability or change on urban areas and human health. Albeit political risk is tangential to the whole question of climatology, political leaders exist as the "lightening rods" to which public attention will be focused if policies to mitigate the effects of climate variability or change are not made or enforced.

Although the primary, secondary, and tertiary effects, data needs, and mitigation strategies expressed in the matrix are category-dependent, there are some common threads that pervade throughout all 10 categories. Improved education of both the public, and decision-makers and leaders, on the potential effects of climate variability and change on urban areas and human health, is essential in developing mitigation strategies for all the categories listed in the table. Also, effective communication by scientists to the public of the possible impacts and dynamics that climate variability or change may have on cities and human health, is paramount to insure that actions can be taken to prepare for or mitigate these effects. Moreover, although not explicitly stated in the matrix, the data both required and used to mitigate the effects of climate variability or change need to be consistent and high quality. This includes providing adequate metadata to support and augment the analytical, modeling, and decision-making processes on how urban areas will be affected by, or affect, climate and what impacts will occur on human health.

A summary of the research needs as related to the 10 categories given in the matrix and the attendant effects, data needs, and mitigation strategies is presented below. These are listed in order of priority to address the critical issues this breakout session has identified on how climate variability and change will impact urban areas and human health in the southeastern United States.

- Air quality is a major concern of urban areas and contributes to a host of environmental and human health problems. Accordingly, surveillance systems that correlate respiratory health to air quality changes resulting from climate variability are needed.

- The urban heat island and land use changes directly contribute to air quality degradation through their influence on photochemical processes. More remotely sensed data and modeling simulations are needed to further evaluate these changes.

- Urbanization has several significant effects on local and regional climate such as elevated air temperature, altered precipitation patterns, sunlight intensity, etc. In particular, climate variability or changes that effect an increase in temperature and intensity in rainfall will be exacerbated over cities because of urban climatological processes. More research into the local and regional effects of urbanization on climate are needed to better understand the magnitude of these impacts.

- Hurricanes account for a major loss of property and infrastructure in the southeastern U.S. The impacts of hurricanes has become even more devastating as major increases in population centers have occurred along the Gulf of Mexico and the Atlantic Coast in the southeastern U.S. Research needs to be conducted on the interaction of population growth, land use/land cover change, and projected impact of future hurricanes on cities located on the coasts of the southeastern region.

- Water supply, volume, and quality are critical to sustaining urban environments. Changing precipitation trends and intensities are of particular interest in monitoring water levels (groundwater and surface), runoff capacity, reservoir management, and water quality.

- Regional climate variability has the potential to impact energy usage from extreme temperature changes. Better prediction of climatic events and trends that effect energy usage is needed, such as summer heat waves or extended wet periods as a result of ENSO.

- Peak rainfall events are especially important to urban areas due to stormwater runoff and flooding concerns. Better historical data and prediction of peak events both in frequency and intensity are needed to minimize adverse public health and urban infrastructure impacts.

- Data are needed to identify susceptible populations that will be affected by changes in climate extremes and variability. This would include conditions caused by solar radiation (skin cancer) or individuals with immunodeficiency susceptible to infectious diseases from climate-effected vectors. The elderly, and maternal-child susceptibilities are most vital.

- Training programs for public health officials need to redeveloped for the recognition and proper reporting of conditions directly and remotely caused by climate variability and change.

- The cost of local and regional climate variability impacts on urban areas needs to be evaluated for planners and decision makers.

- Food supply to urban areas is susceptible to climate variability. Climate variability research is needed on the impact of the production and distribution of food supply, such as temperature, precipitation extremes, and severe storms. Studies should include an investigation of the possible affects on food produced in close proximity to, or distant from, the city.

- Planners and decision makers have an expressed need for more comprehensive data on the affects of climate variability and change on urban infrastructure.

g. WATER RESOURCES

John Schaake, NOAA/NWS
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Todd Tisdale, South Florida Water Management District

1. Executive Summary

Although the Southeast receives a great deal precipitation and has an extensive system of water supply projects, water demand is beginning to exceed the available supply due to increases in population, urbanization, and agricultural uses. Even in this relatively water-rich area, serious conflicts have emerged over how water resources should be used and how the water systems should be operated. Competition for water in the Southeast is currently exacerbated by climate variability and would be further aggravated by potential changes in climate and any increases in variability. The key issue facing water managers in the Southeast is ‘How do we equitably allocate water in the face of growing populations and increased competition among water uses ... and climatic uncertainty ?’

To address this issue, better water management approaches are needed. A wide range of coping strategies were identified, including: water use reallocation; demand-side management; innovative supply side management; flexible and adaptive approaches to water management; improved methods for analyzing trade-offs between alternative uses; and new patterns for negotiation and problem resolution. Some of the most difficult challenges facing water managers in the Southeast are not of a technical nature, but are of a social and political nature, which require flexible and adaptive institutions, legal frameworks, and problem solving mechanisms.

Additionally, a bridge is needed between the information that can be produced regarding future climate variability and change and the information required to understand the trade-offs between different water management alternatives. This bridge involves the use of hydrologic models that translate climate information into streamflow, water levels, soil moisture, and other hydrologic variables. Also, the reliability of the climate information must be assessed and the uncertainty in possible future events must be represented quantitatively.

To assure that appropriate bridges are built and that available climate information is used as well as possible, a few demonstration or pilot projects should be undertaken. These must involve water resources stakeholders, water systems operators, appropriate government agencies and the scientific community.

As a first step, it is recommended that climate projects such as the Global Water and Energy Cycle Experiment (GEWEX), Continental-Scale International Project (GCIP) be encouraged to undertake demonstration projects in the Southeast. These projects will: (1) accelerate the development of models and information related to the prediction of precipitation, soil moisture, temperature, and streamflow over forecast periods up to a year ahead and (2) test model and information value to water resources interests.

2. Current Concerns and Stresses

The overriding water resources issue in the Southeast is demand for water, which is beginning to exceed the available supply. As a result, competition among water users is intensifying. Water use conflicts are becoming more prevalent despite the fact that precipitation in the region is relatively abundant and an extensive system of water storage reservoirs exists throughout the Southeast. Water demands, however, have grown significantly and become more complex due to rapid population growth, increased urbanization, rising agricultural uses and increased irrigation, and changing public priorities. Reservoir systems, such as the Tennessee Valley Authority (TVA) reservoir system, designed for the traditional needs of water supply, flood control, navigation, and power production, must now accommodate public demands for recreation and improved water quality. Large metropolitan areas such as Atlanta, Georgia must compete with other states for water, as evidenced by Alabama suing the U.S. Army Corps of Engineers after reservoir storage in Corps projects was reallocated from hydropower to water supply for Atlanta. In south Florida, the Department of Interior, Corps of Engineers, South Florida Water Management District, and a suite of other private and public groups are working together to restore ecosystem functions of the Everglades and resolve conflicts over water use by agricultural, urban, and environmental interests. Additionally, water quality issues have become increasingly important as degraded quality and salinity intrusion resulting from depleted water tables renders water unavailable for intended uses, thereby increasing water demand as well as reducing the utility of the available supply.

As water conflicts in the Southeast have intensified, it is become apparent that there are inadequate mechanisms for the equitable allocation of water. It appears that many important water resources issues are not of a technical nature, but are political, social, economic, and institutional/organizational issues. A major concern in the Southeast is how to develop flexible and adaptive institutions/organizations, legal frameworks, and problem solving mechanisms to allocate water among competing uses.

Other water resources stresses in the Southeast are of a localized nature and/or important to specific hydrologic systems, such as inland freshwater river basins, coastal areas, or the wetlands of the Everglades. Some of the more important water resources problems in the Southeast are related to:

- Saltwater intrusion
- Sea level rise
- Water temperature (assimilative capacity, power, water quality)
- Extreme events (hurricanes, tornados)
- Sensitive ecological areas (wetlands, estuaries, Everglades)
- Groundwater overdraft and contamination
- Urbanization & aging infrastructures
- Instream flow needs
- Nonpoint source pollution (agricultural, mine, toxic)
- Loss and lack of data and monitoring

3. Implications of Climate Change

In the Southeast, as snowmelt is minimal, the primary climatic factor which directly influences water resources is the magnitude and distribution of precipitation. Expected increases in temperature resulting from climatic change will impact water availability through changes in evapotranspiration, soil moisture, and water quality, as well as by increasing water demand. At the present time, general circulation model (GCM) predictions for the Southeast yield varying results, with some GCM's predicting increases in precipitation, and others predicting reductions. Consequently, it is difficult to predict precise impacts to current water uses, as a wetter vs. a dryer climate would have very different implications. In general, however, regardless of the direction, changes in climatic conditions will exacerbate existing stresses and intensify competition among water uses. Policy makers will come under increased pressure to improve water management.

4. Coping Strategies

Many coping strategies exist to solve problems associated with climate variability and change, including:

- Water use reallocation
- Demand-side management
- Innovative supply side management
- Integrated river basin management
- Flexible and adaptive approaches to water management
- Effective approaches for resolving water use conflicts

Each strategy is examined briefly below.

4.1 Water Use Reallocation

Water use reallocation requires reprioritizing needs and developing allocation optimization techniques. Optimization techniques must consider the reprioritized needs and water costs. Costs are either direct or indirect. A direct cost is the value of water, and an indirect cost is the price associated with not having sufficient water for some activity (i.e. recreation).

4.2 Demand Side Management

Demand side management involves the re-use, efficient use, and conservation of water by users. Examples include using grey water for irrigating golf courses, using flow-reduction devices in plumbing fixtures, and xeriscape landscaping techniques.

4.3 Innovative Supply Side Management

Examples of innovative supply side management techniques are water credits, creating water markets, developing pricing strategies, facilitating inter-basin transfers, and improving existing infrastructures. The use of water credits will require oversight by governmental agencies. Water markets, used in the west, will require that governmental agencies give up some of their traditional water management powers. Pricing strategies will change people's views of water as an abundant, relatively inexpensive commodity. Interbasin transfers will require more flexibility on the part of water management agencies, and the funding required for infrastructure improvement will require increased taxes or cut-backs in other governmental services.

4.4 Integrated River Basin Management

Integrated river basin management uses multi-governmental and stakeholder teams to solve water problems that cross political (i.e. jurisdictional) and professional (e.g. engineering, ecology, planning, social science, economics) boundaries. These teams must use flexible and adaptive approaches to address basin-specific problems. Flexibility is needed to cope with annual climatic variability, and adaptability is needed to deal with changing water use patterns (e.g. new demands, changes in demands).

4.5 New Patterns for Negotiation and Problem Solving

An effective approach for resolving water use conflicts is collaborative problem solving by multi-level governmental and stakeholder teams. For example, Florida, Georgia, Alabama, and the Corps of Engineers created interstate commissions to develop equitable allocations of water taken from basins shared by the three states and containing water control projects operated by the Corps of Engineers. While implementation will vary from one situation to the next, collaborative problem solving is a powerful strategy for resolving water use conflicts.

5. Information Needs and R&D

5.1 Improved Communication with Decision Makers and the Public

Relevant information must be presented concisely and clearly. This should include assessments of consequences, risk, uncertainty and trade-offs among these factors for different alternatives. Improved communication with the public also improves chances of public buy-in for initiatives undertaken to reduce the stresses caused by climate variability and change.

5.2 Improved Modeling Capabilities

Critical parts of the bridge between climate information and water resources decisions are: (1) hydrologic models that translate climatic variables into streamflow and (2) water resources models to simulate the operations of reservoirs, diversions, and other water projects. Hydrologic models must represent flow conditions at both gaged and ungaged locations. One of the most costly and difficult steps in hydrologic modeling is to estimate model parameters. Better hydrologic models are needed with parameters that can more easily be estimated, both by calibration using historical data and by a priori means for ungaged locations. Improved water resources systems models are needed to represent system components that can be operated or controlled and for which decisions must be made.

5.3 Improved Decision Making Tools

Decision support systems are needed to present information and help users understand the relevancy of complex information sets. These systems must be flexible, adaptable to changing user interests, and able to integrate all relevant information. They must incorporate uncertainty into analyses and express outcomes in terms of probabilities. To help users handle complexity, decision support systems must accommodate a hierarchy of system scale definitions.

5.4 Maintenance of Long-term, Continuous Data

Long-term, continuous data are needed as a record of past and present climatic and hydrologic conditions, and to show how conditions have changed over time. The data record should be of sufficient temporal resolution to display short term variabilities and long term changes. Towards this end, historical data sets must be preserved, current monitoring continued, and if needed, new monitoring efforts initiated.

5.5 Improved Weather and Climatic Information and Forecasts

Weather and climate information and forecasts have started to be produced in a probabilistic context. This includes ensemble predictions from weather and climate prediction models. Each member of an ensemble is intended to represent an equally-likely event so that probabilistic estimates can be made. Ensemble members can be input to hydrologic models to produce an ensemble of hydrologic model outputs. Similarly, hydrologic model ensemble members can be input to water resources systems models. Because all models have limitations and biases and only can approximate real world complexity, appropriate data analysis steps are necessary to process the output information from one model before using it as input to the next model.

It is essential that research be continued to improve the reliability of the weather, climate and hydrologic forecast models. Also, research is needed to ensure that uncertainty is adequately quantified.

Forecast information is needed over a wide range of time horizons. Water resource system operations require forecasts from a few days to a year or two into the future. Water resources planning involves time horizons of many decades into the future. A key issue for planning is how to use historical climate information with results from climate change studies.

It is essential that the hydrologic processes (i.e. rainfall) simulated by weather and climate models be accurately simulated. The hydrologic information produced by these models is most important for water resources applications.

5.6 Improved Technologies for Conservation, Efficiency and Re-use

To meet increasing water demands, and the possible reduction of supplies, improved technologies for water conservation, efficient use and re-use are needed. These technologies should address domestic, industrial, hydropower, and irrigation uses. Emphasis will be on maximizing resource use (e.g. development of turbines and generators to maximize hydropower production, irrigation techniques that minimize evaporation losses).

5.7 Flexible Institutions and Mechanisms for Resolving Conflict

Conflict resolution is best handled by institutions that can adjust their operational strategies in accordance with a changing environment. Environmental change is impacted by climate variability/change, new water demands, and changes in old demands. Institutions that can adjust operational strategies usually are empowered to provide multiple services, instead of just one. For example, a water management agency that provides flood protection, hydropower, and water for consumptive use can adjust much better to new demands for services than an agency that only provides hydropower.

5.8 Demonstration Projects

Demonstration projects are needed to test if research results actually meet user needs and to assist in the development of more useful forecast information. Also, these projects should be done in a realistic institutional setting to assure that diverse public and private interests are represented and reasonable opportunity exists to correctly assess the potential value of new information.

5.9 Statistical Methods and Applications Strategies

Creative statistical approaches are needed to deal with uncertainty in forecasts of climate variability and change and to evaluate the reliability of these forecasts. Statistical analyses used in most water resources planning, design and management are based on the assumption of a stationary climate. Methods for dealing with a changing or non-stationary climate should be explored and more widely practiced. Also, statistical downscaling techniques are needed to account for fine-scale climatic variability. Fine-scale variability is important to the behavior of non-linear hydrologic models but is not provided by climate models. Additionally, issues such as the potential impact of climate change on the probable maximum precipitation (PMP) and probable maximum flood (PMF) could have important implications for design criteria and dam safety.

APPENDIX A:
Potential Impacts of Climate Variability and Change to South Florida

Background

Water managers in south Florida are concerned primarily with flood control, water supply, and environmental protection. To accomplish these functions, water is moved through an extensive network of canals, which are connected to natural lakes and large water impoundments. Water movement is controlled by numerous pumps and gravity driven, flow control structures. The most notable of south Florida's lakes is Lake Okeechobee. The diked impoundments, called water conservation areas, encompass large tracts of the original Everglades.

South Florida's landscape is widely varied. The Southeast coast (Dade, Broward, and Palm Beach Counties) is a major urban center, with a population of over three million people. This area continues to grow and expand at a high rate. Agriculture, an important industry in south Florida, is a major sugar producer and provides large quantities of vegetables to the east coast of the United States during the winter. Critus also is very important. Large tracts of land are devoted to environmental preservation and recreation. National and state parks and wildlife refuges are found throughout south Florida. Lake Okeechobee is a major recreational resource. These areas provide wildlife habitat, have navigable waterways, and constitute the basis of a highly profitable recreation/ecotourism industry.

The operation of south Florida's water management system requires that water levels and deliveries be kept within certain limits. Excessive water or drought impact the ability of water managers to control flooding, supply water, and protect the environment. Specific examples are given below.

Water levels in canals are directly related to groundwater levels. During south Florida's wet season (June to October), canal levels are kept low to improve drainage and minimize flooding. During extremely wet periods, if canal levels cannot be kept sufficiently low, water tables rise towards the land surface and the possibility of flooding increases. During the dry season, canal levels are managed to keep the water table near the root zone in agricultural areas and to minimize salt water intrusion along the coast. During extended dry periods, reduced canal levels enable the water table to recede below the root zone, requiring increased groundwater pumping for irrigation. Lower groundwater levels also increase salt water intrusion.

Water levels in Lake Okeechobee must be kept within a certain range to prevent environmental degradation. If levels are too low, turbidity increases in open water areas (adversely impacting the pelagic environment). Too much water damages submerged aquatic vegetation because of reduced light transmittance through the water column. Environmental degradation impacts wildlife habitat, navigation, and recreation/ecotourism.

The Caloosahatchee and St. Lucie River estuaries (located on Florida's west and east coasts, respectively) receive freshwater inflows from their watersheds and Lake Okeechobee. During extremely wet periods, large quantities of fresh water are discharged to these estuaries. During extended dry periods, sufficient fresh water may not be available. Too little or too much freshwater adversely impacts estuarine environments, causing the degradation of wildlife habitats and economic losses to the recreation/ecotourism industry.

A series of stormwater treatment areas (STAs) will be built to remove phosphorus from water discharged to the Everglades from Lake Okeechobee and the Everglades Agricultural Area, south of Lake Okeechobee. Excess phosphorus comes from Lake Okeechobee and agricultural activities. The STAs will contain a variety of aquatic plants that require a specific range of water depths. Too much or too little water will harm the plants. Too much water also will reduce residence times in the STAs and require some flows to by-pass the STAs. Thus, water discharging to the Everglades may contain higher phosphorus concentrations.

Water Resources Issues

Based on the above discussion, important water resources issues in south Florida are: water supply; flood control; and environmental protection. During extended dry periods, sufficient water may not be available to satisfy the competing demands of urban areas, agriculture, and the environment. During periods of extreme precipitation, excess water may not be conveyed out of the water management system fast enough to prevent flooding. A growing population is adversely impacting all three of these issues.

Connections Between Water Resources Issues and Climate

Rainfall variability impacts how the water management system is operated for water supply, flood control and environmental protection. More rainfall means an increased potential for flooding, which adversely impacts agriculture, urban areas, and the environment. Less rainfall increases competition for water. Temperature variability affects water supplies, due to changes in evapotranspiration, and demand. Thus, as with the rest of the Southeast, climatic changes in South Florida will exacerbate existing stresses and intensify competition among water uses. Decision makers will come under increased pressure to improve water management.

Coping Strategies and Management Needs

The coping strategies and management needs for south Florida are basically the same as for the rest of the Southeast. Because south Florida's climate, weather, hydrology, and water management systems are significantly different from much of the Southeast, a separate suite of climate, meteorology, hydrology, and operations models are needed. To ensure that these models work correctly and properly interface with one another, south Florida water management agencies should become involved in demonstration projects involving technology transfers from research institutions to public agencies and private organizations. Research also is needed on how to best modify/reconfigure the water management system to better handle climate variability and change.

Appendix B
Workshop on Climate Variability and Water Resource Management in the Southeastern United States
Vanderbilt University
Nashville, Tennessee
June 25-27, 1997

AGENDA

Time	Subject	Speaker
June 25, 1997		
7:00	Registration	
8:00	Plenary: Introduction	Dr. John Venable, Vanderbilt U., *Associate Provost*
8:05	Plenary: Roadmap of workshop	Dr. R. Ritschard, *UAH/GHCC*
8:15	Plenary: National Perspective	Dr. Jack Gibbons, *President's Science Advisor*
8:30	Plenary: Current Climate Variability in Southeast	Dr. Jim O'Brien, *Florida State University*
9:30	Break	
10:00	Plenary: Regional Perspectives on Climate Variability and Impacts	Dr. Michael Helfert, *South Carolina Department of Natural Resources*
11:00	Plenary: Keynote Talk	Bill Campbell, *Mayor of Atlanta*
12:00	Plenary: Educational Aspects of Climate	Dr. Roger Bybee, *National Research Council*
12:30	Plenary: Breakout Session Charge	Dr. Jerry Melillo, *Office of Science and Technology Policy*
12:45	Lunch	
1:45	Breakout Sessions	
5:00	Exhibitor Presentations	
6:00	Dinner at University Club of Nashville	Vice President Al Gore, *Guest Speaker*
June 26, 1997		
8:00	Plenary: Panel Discussion on Stakeholder and Scientist Perspectives	Dr. Roger Pielke, Jr., *National Center for Atmospheric Research (NCAR), Panel Leader* Dr. Linda Mearns, *NCAR* Margaret Davidson, *Coastal Services Center/NOAA* Dr. R. Nick Keener, *Duke Power*
9:00	Plenary: Global Climate Change Trends	Robert Quayle, *Natl. Climatic Data Center/NOAA*
10:00	Break	
10:30	Plenary:Examples of Regional Applications	Dr. Doug Rickman, *NASA/MSFC*, Session Chair Wilson Orr, *City of Scottsdale* Dr. Roger Clapp, *Hydrology Consultant* Paul Trimble, *South Florida Water Mgmt. District*
11:30	Luncheon	Dr. Virginia Burkett, *USGS, Guest Speaker*
1:00	Breakout Sessions	
5:00	Exihibitor Presentations	
June 27, 1997		
8:00	Breakout Session Reports and Discussion	
12:00	Adjourn Workshop	